The EXFILT Project

Timothy Daly, Charles Howard, Ravi Starzl

Nanjie Chenglie, Hua Tang

August 14, 2015

> I believe that the time is ripe for significantly better documentation of programs, and that we can best achieve this by considering programs to be works of literature. Hence, my title "Literate Programming".
>
> Let us change our traditional attitude to the construction of programs: Instead of imagining that our main task is to instruct a computer what to do, let us concentrate rather on explaining to human beings what we want a computer to do.
>
> – **Donald Knuth** [50]

This is a literate program. It is oriented toward communicating with people and, as a side-effect, communicating with the machine. All of the programs, data, and tests are included and are extracted from this document to build the system.

Contents

Chapter 1

Preface

Exfiltration of confidential data is a growing concern as collections of confidential information grow larger, these become high-value targets. One recent example is the loss of 4.2 million records containing the background checks for top secret security clearance were exfiltrated from the Office of Personnel Management.

There are several layers of defense that could have, and should have, been applied to this data. Apparently there was no mechanism to recognize that this data was being stolen. At minimum, there ought to be a last line of defense alert system.

A last line of defense would at least make people aware that confidential data was being copied. It should monitor the network for confidential data transfer and, if any is found, raise an alarm.

The idea behind the current work is to prototype such a last line of defense. We consider marking confidential documents held in storage and examining data streams to detect that a confidential document is being exfiltrated.

In this simple prototype we make several simplifying assumptions.

First, we assume that the data is marked by computing a SHA1 hash. This hash can be kept in a network device table. The network device computes a hash of document traffic. If the traffic hash matches a hash in the table then it is a confidential document and an alert is issued. The "marker" can be anything but SHA1 is simple.

Second, we assume that our device is "plug-and-play" in that it can be plugged into the network just prior to leaving the premise. It could be applied in an internal network if there is a secure perimeter around the data.

Third, we assume that the data in transit is a copy of the data in storage. That is, there is no encryption or obfuscation applied to the data between reading from storage and arriving at our device.

Our prototype is originally implemented in C running on a PC in order to examine issues. However, it is clear that such an implementation cannot keep up with network traffic.

After completing the first prototype we moved on to a Field Programmable Gate Array (FPGA) hardware implementation. This can operate at network speeds. We have a VHDL hardware interface which feeds a primitive VHDL CPU. The CPU is programmed in Forth, a stack based language.

1.1 Overview

We set up dual laptops, one containing the confidential information and one trying to exfiltrate it. We used Wireshark to get packet traces. We wrote C code to extract the confidential ile on the wire and recognize that it was confidential. This was the initial prototype plan.

Once that prototype was done we moved to an FPGA implementation. The implementation uses a VHDL J1 processor which can be programmed in Forth. We are working to get the bytes off the wire, into memory, and checking (using SHA1 in Forth) that we have the confidential file. This is a hardware implementation of the prototype.

Chapter 2

EXFILT Plan Steps

EXFILT will begin as a software-based set of technologies to prevent sensitive information from traveling outside of a computer network. The intent of the initial version is to create Intellectual Property and a prototypical Proof of Concept to be used for fundraising. As such, hardware/firmware based implementations involving FPGAs, microprocessors and other embedded logic controllers are out of scope; but might be developed at a later date. Extensibility and interoperability with potential future non-software based implementations are not of major concern when building the initial prototype version.

Version 0.0

The goal for this iteration is to construct a SNORT plugin (in C) for use with Wireshark. The plugin will use deep packet inspection to detect a transfer of sensitive information by looking for the presence of a SHA1 hash. To allow us to focus on the complexities of getting a basic plugin functioning, the only protocol and transfer type addressed by this version will be an FTP Copy operation; and test data will simply be unencrypted plain-text files. Other formats and modes like .docx and .pdf files, or email attachments will be addressed in later iterations.

When the plugin detects sensitive information it will log the date/time, origin IP, destination IP, and other details depending on availability and usefulness. At this stage it will not attempt to terminate or block the transmission of data.

Version 0.1

This iteration involves the construction of a proxy server-like buffer (in Java) for accumulating the entire set of packets in a transmission, for subsequent inspection of file attributes (such as file type), and syntactic analysis against a cohesive file. The buffering system at this point does not need to implement any filtering/detection methods. It simply needs to be able to accumulate the packets in a transmission, then either stop the transmission by sending it forward, or forward the transmission on to its final destination.

Version 0.2

This iteration of the prototype will include one or more of the following, depending on priorities, time, resources and discoveries as they stand at the completion of Version 0.1:

A. An interface for end users to define syntactic filters (words, phrases and patterns) to be

used for detecting sensitive information in transmissions accumulated in the Buffering system built in v0.1

B. Automated redaction of sensitive information through replacement of detected sensitive information patterns with innocuous text prior to re-transmission to the final destination

C. Support for file formats other than plain text (e.g.: .docx, .pdf, .xls, etc) Open source, Java-based readers for various file formats might be used for this effort. Since the goal of Version 0 is a functional Proof Of Concept, proprietary document readers with lower latency can be built in later development efforts.

D. Support for filtering email attachments, as well as communication protocols other than FTP. This effort could encompass changes to both the Buffering and Filtering system and the SNORT plugin built in version 0.0.

Chapter 3

Threats and Risks

3.1 Threats

- loss of customer data
- loss of corporate data
- theft of capital equipment
- business disruption
- reduced productivity
- increased expense
- regulatory violation
- loss of public trust
- stock loss

Risk = probability x cost

3.1.1 Insider Threats

ISO 17799 Code of Practice or Information Security Management Internal Controls (COSO) Committee of Sponsoring Organizations of the Treadway Commission (CobiT) Control Objective for Information and related Technology

Operational Security:

http://securityaffairs.co/wordpress/37368/security/operational-securit-user-education.html

Chapter 4

AI and Exfiltration

4.1 The Problem

Exfiltration is rarely accidental and confidential information does not move itself. The key question becomes "How to identify the actor?"

We can take a bottom-up approach to the problem. This involves several layers, some of which are traditional and some which are not yet in use.

At the network layer we need to have "sensors" which can detect the movement of confidential data across the security boundary. Various sensing techniques exist. Indeed, we are building a network sensor prototype which will detect an exfiltration.

At the monitoring layer we need rules that specify what actions to take. Rule-based systems, usually built on SNORT or Linux IPTables, allow actions such as DROPing a packet. However, this layer of rules is too close to the metal and cannot see exfiltration events over normal traffic avenues like FTP or email.

At the alert level we need network logging, again usually using things like IPTable LOG rules.

There are issues that arise at the logging layer and above. For any network size, logging is useless if the logs are not reviewed. But, almost no matter the size of the network, the number of people available to review the logs is not sufficient to act on each event.

A network attack can easly swamp a network log file so that it either contains too many entries or simply runs out of storage.

Worse, even if every event was tracked, there needs to be someone who can provide an overview of all the events to extract the common elements. These common elements need to be "backtracked" to find the actor(s).

This "analysis" layer is usually missing from network security. At best it occurs as a post-mortem after a network breach. But given the volume of traffic locally or in a data center, the likelyhood of finding an exfiltration pattern is small.

4.2 An Artificial Intelligence Approach

Traditional Artificial Intelligence (AI) techniques can be applied to this problem. Large volumes of data containing small patterns of information are the normal domain of these systems.

Usually the "sensors" are human-like, such as cameras for "eyes", microphones for "ears", and robot arms for "actuators". But that does not have to be the case. In a network environment the "sensing" equipment are low-level hardware and SNORT/IPTables firewall rules.

The AI problem, given the logs and active alerts on the sensors, is to find elfiltration events, correlate the events with patterns, and from those patterns identify the likely actor(s).

Chapter 5

Background

- **Packet filtering** https://www.youtube.com/watch?v=XHlqIqPvKw8
- **Wireshark tutorial** https://www.youtube.com/watch?v=Lu05owzpSb8
- **Art of Packet Analysis** https://www.youtube.com/watch?v=Qd6uDg9OGxM
- **TCP/IP Packet analysis tutorials** https://www.youtube.com/watch?v=jWJIGqW6PrY&list=PLD57FE11C7A09034F&index=1

5.1 Protocols Introduction

The File Transfer Protocol (FTP) is a standard network protocol used to transfer computer files from one host to another host over a TCP-based network, such as the Internet.[10] FTP is built on a client-server architecture and uses separate control and data connections between the client and the server. FTP users may authenticate themselves using a clear-text sign-in protocol, normally in the form of a username and password, but can connect anonymously if the server is configured to allow it. For secure transmission that protects the username and password, and encrypts the content, FTP is often secured with SSL/TLS (FTPS). SSH File Transfer Protocol (SFTP) is sometimes also used instead, but is technologically different.

FTP may run in active or passive mode, which determines how the data connection is established.[11] In both cases, the client creates a TCP control connection from a random, usually an unprivileged, port N to the FTP server command port 21. In active mode, the client starts listening for incoming data connections from the server on port M. It sends the FTP command PORT M to inform the server on which port it is listening. By default, M=N. The server then initiates a data channel to the client from its port 20, the FTP server data port. In situations where the client is behind a firewall and unable to accept incoming TCP connections, passive mode may be used. In this mode, the client uses the control connection to send a PASV command to the server and then receives a server IP address and server port number from the server,[11, 12] which the client then uses to open a data connection from an arbitrary client port to the server IP address and server port number received.[13] Both modes were updated in September 1998 to support IPv6. Further changes were introduced to the passive mode at that time, updating it to extended passive mode.[14]

The server responds over the control connection with three-digit status codes in ASCII with an optional text message. For example "200" (or "200 OK") means that the last command was successful. The numbers represent the code for the response and the optional text represents a human-readable explanation or request (e.g. ¡Need account for storing file¿).[10] An ongoing transfer of file data over the data connection can be aborted using an interrupt message sent over the control connection.

- FTP (File Transfer Protocol)
  - Introduction video:
    http://www.lynda.com/FTP-tutorials/What-FTP/189068/364891-4.html
  - Standard RFC (Request for Comments):
    - FTP Security Extensions: RFC 2228
      http://www.rfc-editor.org/rfc/rfc2228.txt
    - Internationalization of the File Transfer Protocol: RFC 2640
      http://www.rfc-editor.org/rfc/rfc2640.txt
    - Encryption using KEA and SKIPJACK: RFC 2773
      http://www.rfc-editor.org/rfc/rfc2773.txt
    - Extensions to FTP: RFC 3659
      http://www.rfc-editor.org/rfc/rfc3659.txt
    - FTP Command and Extension Registry: RFC 5797
      http://www.rfc-editor.org/rfc/rfc5797.txt
    - File Transfer Protocol HOST Command for Virtual Hosts: RFC 7151
      http://www.rfc-editor.org/rfc/rfc7151.txt
- ARP (Address Resolution Protocol)
  - Introduction video:
    https://www.youtube.com/watch?v=2ydK33mPhTY
  - Standard RFC (Request for Comments):
    - IANA Allocation Guidelines for the Address Resolution Protocol (ARP): RFC 5494 http://www.rfc-editor.org/rfc/rfc5494.txt
    - A Reverse Address Resolution Protocol: RFC 903
      http://www.rfc-editor.org/rfc/rfc903.txt
    - Inverse Address Resolution Protocol: RFC 2390
      http://www.rfc-editor.org/rfc/rfc2390.txt

    * Address Resolution Protocol (ARP) Mediation for IP Interworking of Layer 2 VPNs: RFC 6575
      http://www.rfc-editor.org/rfc/rfc6575.txt
    * FTP Command and Extension Registry: RFC 5797
      http://www.rfc-editor.org/rfc/rfc5797.txt
    * File Transfer Protocol HOST Command for Virtual Hosts: RFC 7151
      http://www.rfc-editor.org/rfc/rfc7151.txt

- HTTP (Hypertext Transfer Protocol)

  - Introduction video:
    https://www.youtube.com/watch?v=uvSIR2RhdXk
  - Standard RFC (Request for Comments):

    * Character Set and Language Encoding for Hypertext Transfer Protocol (HTTP) Header Field Parameters: RFC 5987
      http://www.rfc-editor.org/rfc/rfc5987.txt
    * Use of the Content-Disposition Header Field in the Hypertext Transfer Protocol (HTTP): RFC 6266
      http://www.rfc-editor.org/rfc/rfc6266.txt
    * Hypertext Transfer Protocol (HTTP/1.1): Message Syntax and Routing: RFC 7230
      http://www.rfc-editor.org/rfc/rfc7230.txt
    * Hypertext Transfer Protocol (HTTP/1.1): Semantics and Content: RFC 7231
      http://www.rfc-editor.org/rfc/rfc7231.txt
    * Hypertext Transfer Protocol (HTTP/1.1): Conditional Requests: RFC 7232
      http://www.rfc-editor.org/rfc/rfc7232.txt
    * Hypertext Transfer Protocol (HTTP/1.1): Range Requests: RFC 7233
      http://www.rfc-editor.org/rfc/rfc7233.txt
    * Hypertext Transfer Protocol (HTTP/1.1): Caching: RFC 7234
      http://www.rfc-editor.org/rfc/rfc7234.txt
    * Hypertext Transfer Protocol (HTTP/1.1): Authentication: RFC 7235
      http://www.rfc-editor.org/rfc/rfc7235.txt
    * The Hypertext Transfer Protocol Status Code 308 (Permanent Redirect): RFC 7538
      http://www.rfc-editor.org/rfc/rfc7538.txt
    * Hypertext Transfer Protocol Version 2 (HTTP/2): RFC 7540
      http://www.rfc-editor.org/rfc/rfc7540.txt

- HTTPS (Hypertext Transfer Protocol Secure)

  - Introduction video:
    https://www.youtube.com/watch?v=JCvPnwpWVUQ

  - Standard RFC (Request for Comments):

    * Internet Printing Protocol (IPP) over HTTPS Transport Binding and the 'ipps' URI Scheme: RFC 7472
      http://www.rfc-editor.org/rfc/rfc7472.txt

- SMTP (Simple Mail Transfer Protocol)

  - Introduction video:
    https://www.youtube.com/watch?v=1X3dX2JEhLE
  - Standard RFC (Request for Comments):

    * SMTP Service Extension for Message Size Declaration: RFC 1870
      http://www.rfc-editor.org/rfc/rfc1870.txt
    * SMTP Service Extension for Command Pipelining: RFC 2920
      http://www.rfc-editor.org/rfc/rfc2920.txt
    * SMTP Service Extension for 8-bit MIME Transport: RFC 6152
      http://www.rfc-editor.org/rfc/rfc6152.txt
    * SMTP Service Extension for Remote Message Queue Starting: RFC 1985
      http://www.rfc-editor.org/rfc/rfc1985.txt
    * SMTP Service Extension for Returning Enhanced Error Codes: RFC 2034
      http://www.rfc-editor.org/rfc/rfc2034.txt
    * Deliver By SMTP Service Extension: RFC 2852
      http://www.rfc-editor.org/rfc/rfc2852.txt
    * SMTP Service Extensions for Transmission of Large and Binary MIME Messages: RFC 3030
      http://www.rfc-editor.org/rfc/rfc3030.txt
    * SMTP Service Extension for Secure SMTP over Transport Layer Security: RFC 3207
      http://www.rfc-editor.org/rfc/rfc3207.txt
    * A No Soliciting Simple Mail Transfer Protocol (SMTP) Service Extension: RFC 3865
      http://www.rfc-editor.org/rfc/rfc3865.txt
    * SMTP Service Extension for Message Tracking: RFC 3885
      http://www.rfc-editor.org/rfc/rfc3885.txt
    * SMTP and MIME Extensions for Content Conversion: RFC 4141
      http://www.rfc-editor.org/rfc/rfc4141.txt
    * SMTP Submission Service Extension for Future Message Release: RFC 4865
      http://www.rfc-editor.org/rfc/rfc4865.txt
    * A Registry for SMTP Enhanced Mail System Status Codes: RFC 5248
      http://www.rfc-editor.org/rfc/rfc5248.txt
    * SMTP Extension for Internationalized Email: RFC 6531
      http://www.rfc-editor.org/rfc/rfc6531.txt

    * Email Greylisting: An Applicability Statement for SMTP: RFC 6647
      http://www.rfc-editor.org/rfc/rfc6647.txt
    * The Require-Recipient-Valid-Since Header Field and SMTP Service Extension: RFC 7293
      s http://www.rfc-editor.org/rfc/rfc7293.txt

- DHCP (Dynamic Host Configuration Protocol)

  – Introduction video:
    https://www.youtube.com/watch?v=CgsRdy0iCiE
  – Standard RFC (Request for Comments):

    * Interoperation Between DHCP and BOOTP: RFC 1534
      http://www.rfc-editor.org/rfc/rfc1534.txt
    * DHCP Options for Novell Directory Services: RFC 2241
      http://www.rfc-editor.org/rfc/rfc2241.txt
    * DHCP Option for The Open Group's User Authentication Protocol: RFC 2485
      http://www.rfc-editor.org/rfc/rfc2485.txt
    * DHCP Option to Disable Stateless Auto-Configuration in IPv4 Clients: RFC 2563
      http://www.rfc-editor.org/rfc/rfc2563.txt
    * DHCP Options for Service Location Protocol: RFC 2610
      http://www.rfc-editor.org/rfc/rfc2610.txt
    * DHCP for IEEE 1394: RFC 2855
      http://www.rfc-editor.org/rfc/rfc2855.txt
    * The Name Service Search Option for DHCP: RFC 2937
      http://www.rfc-editor.org/rfc/rfc2937.txt
    * The User Class Option for DHCP: RFC 3004
      http://www.rfc-editor.org/rfc/rfc3004.txt
    * The IPv4 Subnet Selection Option for DHCP: RFC 3011
      http://www.rfc-editor.org/rfc/rfc3011.txt
    * Authentication for DHCP Messages: RFC 3118
      http://www.rfc-editor.org/rfc/rfc3118.txt
    * The DOCSIS (Data-Over-Cable Service Interface Specifications) Device Class DHCP (Dynamic Host Configuration Protocol) Relay Agent Information Sub-option: RFC 3256
      http://www.rfc-editor.org/rfc/rfc3256.txt
    * Dynamic Host Configuration Protocol (DHCPv6) Options for Session Initiation Protocol (SIP) Servers: RFC 3319
      http://www.rfc-editor.org/rfc/rfc3319.txt
    * Dynamic Host Configuration Protocol (DHCP-for-IPv4) Option for Session Initiation Protocol (SIP) Servers: RFC 3361
      http://www.rfc-editor.org/rfc/rfc3361.txt

* Encoding Long Options in the Dynamic Host Configuration Protocol (DHCPv4): RFC 3396
  http://www.rfc-editor.org/rfc/rfc3396.txt
* Dynamic Host Configuration Protocol (DHCP) Domain Search Option: RFC 3397
  http://www.rfc-editor.org/rfc/rfc3397.txt
* The Classless Static Route Option for Dynamic Host Configuration Protocol (DHCP) version 4: RFC 3442
  http://www.rfc-editor.org/rfc/rfc3442.txt
* Dynamic Host Configuration Protocol (DHCPv4) Configuration of IPsec Tunnel Mode: RFC 3456
  http://www.rfc-editor.org/rfc/rfc3456.txt
* Dynamic Host Configuration Protocol (DHCP) Option for CableLabs Client Configuration: RFC 3495
  http://www.rfc-editor.org/rfc/rfc3495.txt
* Link Selection sub-option for the Relay Agent Information Option for DHCPv4: RFC 3527
  http://www.rfc-editor.org/rfc/rfc3527.txt
* PacketCable Security Ticket Control Sub-Option for the DHCP CableLabs Client Configuration (CCC) Option: RFC 3594
  http://www.rfc-editor.org/rfc/rfc3594.txt
* Key Distribution Center (KDC) Server Address Sub-option for the Dynamic Host Configuration Protocol (DHCP) CableLabs Client Configuration (CCC) Option: RFC 3634
  http://www.rfc-editor.org/rfc/rfc3634.txt
* Stateless Dynamic Host Configuration Protocol (DHCP) Service for IPv6: RFC 3736
  http://www.rfc-editor.org/rfc/rfc3736.txt
* Network Information Service (NIS) Configuration Options for Dynamic Host Configuration Protocol for IPv6 (DHCPv6): RFC 3898
  http://www.rfc-editor.org/rfc/rfc3898.txt
* Vendor-Identifying Vendor Options for Dynamic Host Configuration Protocol version 4 (DHCPv4): RFC 3925
  http://www.rfc-editor.org/rfc/rfc3925.txt
* Reclassifying Dynamic Host Configuration Protocol version 4 (DHCPv4) Options: RFC 3942
  http://www.rfc-editor.org/rfc/rfc3942.txt
* Subscriber-ID Suboption for the Dynamic Host Configuration Protocol (DHCP) Relay Agent Option: RFC 3993
  http://www.rfc-editor.org/rfc/rfc3993.txt
* Remote Authentication Dial-In User Service (RADIUS) Attributes Suboption for the Dynamic Host Configuration Protocol (DHCP) Relay Agent Information Option: RFC 4014
  http://www.rfc-editor.org/rfc/rfc4014.txt

* The Authentication Suboption for the Dynamic Host Configuration Protocol (DHCP) Relay Agent Option: RFC 4030
  http://www.rfc-editor.org/rfc/rfc4030.txt
* Rapid Commit Option for the Dynamic Host Configuration Protocol version 4 (DHCPv4): RFC 4039
  http://www.rfc-editor.org/rfc/rfc4039.txt
* Simple Network Time Protocol (SNTP) Configuration Option for DHCPv6: RFC 4075
  http://www.rfc-editor.org/rfc/rfc4075.txt
* Information Refresh Time Option for Dynamic Host Configuration Protocol for IPv6 (DHCPv6): RFC 4242
  http://www.rfc-editor.org/rfc/rfc4242.txt
* Vendor-Specific Information Suboption for the Dynamic Host Configuration Protocol (DHCP) Relay Agent Option: RFC 4243
  http://www.rfc-editor.org/rfc/rfc4243.txt
* Dynamic Host Configuration Protocol (DHCP) Options for Broadcast and Multicast Control Servers: RFC 4280
  http://www.rfc-editor.org/rfc/rfc4280.txt
* Dynamic Host Configuration Protocol (DHCP) over InfiniBand: RFC 4390
  http://www.rfc-editor.org/rfc/rfc4390.txt
* Dynamic Host Configuration Protocol for IPv6 (DHCPv6) Relay Agent Subscriber-ID Option: RFC 4580
  http://www.rfc-editor.org/rfc/rfc4580.txt
* Dynamic Host Configuration Protocol for IPv6 (DHCPv6) Relay Agent Remote-ID Option: RFC 4649
  http://www.rfc-editor.org/rfc/rfc4649.txt
* The Dynamic Host Configuration Protocol (DHCP) Client Fully Qualified Domain Name (FQDN) Option: RFC 4702
  http://www.rfc-editor.org/rfc/rfc4702.txt
* Resolution of Fully Qualified Domain Name (FQDN) Conflicts among Dynamic Host Configuration Protocol (DHCP) Clients: RFC 4703
  http://www.rfc-editor.org/rfc/rfc4703.txt
* The Dynamic Host Configuration Protocol for IPv6 (DHCPv6) Client Fully Qualified Domain Name (FQDN) Option: RFC 4704
  http://www.rfc-editor.org/rfc/rfc4704.txt
* Timezone Options for DHCP: RFC 4833
  http://www.rfc-editor.org/rfc/rfc4833.txt
* DHCPv6 Relay Agent Echo Request Option: RFC 4994
  http://www.rfc-editor.org/rfc/rfc4994.txt
* DHCPv6 Leasequery: RFC 5007
  http://www.rfc-editor.org/rfc/rfc5007.txt
* The Dynamic Host Configuration Protocol Version 4 (DHCPv4) Relay Agent Flags Suboption: RFC 5010
  http://www.rfc-editor.org/rfc/rfc5010.txt

* DHCP Server Identifier Override Suboption: RFC 5107
  http://www.rfc-editor.org/rfc/rfc5107.txt
* DHCP Options for Protocol for Carrying Authentication for Network Access (PANA) Authentication Agents: RFC 5192
  http://www.rfc-editor.org/rfc/rfc5192.txt
* Discovering Location-to-Service Translation (LoST) Servers Using the Dynamic Host Configuration Protocol (DHCP): RFC 5223
  http://www.rfc-editor.org/rfc/rfc5223.txt
* Control And Provisioning of Wireless Access Points (CAPWAP) Access Controller DHCP Option: RFC 5417
  http://www.rfc-editor.org/rfc/rfc5417.txt
* DHCPv6 Bulk Leasequery: RFC 5460
  http://www.rfc-editor.org/rfc/rfc5460.txt
* Dynamic Host Configuration Protocol (DHCPv4 and DHCPv6) Options for IEEE 802.21 Mobility Services (MoS) Discovery: RFC 5678
  http://www.rfc-editor.org/rfc/rfc5678.txt
* Network Time Protocol (NTP) Server Option for DHCPv6: RFC 5908
  http://www.rfc-editor.org/rfc/rfc5908.txt
* DHCPv6 Options for Network Boot: RFC 5970
  http://www.rfc-editor.org/rfc/rfc5970.txt
* DHCPv4 Lease Query by Relay Agent Remote ID: RFC 6148
  http://www.rfc-editor.org/rfc/rfc6148.txt
* DHCPv4 and DHCPv6 Options for Access Network Discovery and Selection Function (ANDSF) Discovery: RFC 6153
  http://www.rfc-editor.org/rfc/rfc6153.txt
* Lightweight DHCPv6 Relay Agent: RFC 6221
  http://www.rfc-editor.org/rfc/rfc6221.txt
* DHCPv6 Prefix Delegation for Network Mobility (NEMO): RFC 6276
  http://www.rfc-editor.org/rfc/rfc6276.txt
* Dynamic Host Configuration Protocol for IPv6 (DHCPv6) Option for Dual-Stack Lite: RFC 6334
  http://www.rfc-editor.org/rfc/rfc6334.txt
* Definition of the UUID-Based DHCPv6 Unique Identifier (DUID-UUID): RFC 6355
  http://www.rfc-editor.org/rfc/rfc6355.txt
* Relay-Supplied DHCP Options: RFC 6422
  http://www.rfc-editor.org/rfc/rfc6422.txt
* The EAP Re-authentication Protocol (ERP) Local Domain Name DHCPv6 Option: RFC 6440
  http://www.rfc-editor.org/rfc/rfc6440.txt
* Prefix Exclude Option for DHCPv6-based Prefix Delegation: RFC 6603
  http://www.rfc-editor.org/rfc/rfc6603.txt
* Virtual Subnet Selection Options for DHCPv4 and DHCPv6: RFC 6607
  http://www.rfc-editor.org/rfc/rfc6607.txt

    * DHCP Options for Home Information Discovery in Mobile IPv6 (MIPv6): RFC 6610
      http://www.rfc-editor.org/rfc/rfc6610.txt
    * Rebind Capability in DHCPv6 Reconfigure Messages: RFC 6644
      http://www.rfc-editor.org/rfc/rfc6644.txt
    * Kerberos Options for DHCPv6: RFC 6784
      http://www.rfc-editor.org/rfc/rfc6784.txt
    * Client Identifier Option in DHCP Server Replies: RFC 6842
      http://www.rfc-editor.org/rfc/rfc6842.txt
    * The DHCPv4 Relay Agent Identifier Sub-Option: RFC 6925
      http://www.rfc-editor.org/rfc/rfc6925.txt
    * DHCPv4 Bulk Leasequery: RFC 6926
      http://www.rfc-editor.org/rfc/rfc6926.txt
    * Client Link-Layer Address Option in DHCPv6: RFC 6939
      http://www.rfc-editor.org/rfc/rfc6939.txt
    * Triggering DHCPv6 Reconfiguration from Relay Agents: RFC 6977
      http://www.rfc-editor.org/rfc/rfc6977.txt
    * RADIUS Option for the DHCPv6 Relay Agent: RFC 7037
      http://www.rfc-editor.org/rfc/rfc7037.txt
    * Distributing Address Selection Policy Using DHCPv6: RFC 7078
      http://www.rfc-editor.org/rfc/rfc7078.txt
    * Handling Unknown DHCPv6 Messages: RFC 7283
      http://www.rfc-editor.org/rfc/rfc7283.txt
    * DHCP Options for the Port Control Protocol (PCP): RFC 7291
      http://www.rfc-editor.org/rfc/rfc7291.txt
    * DHCPv4-over-DHCPv6 (DHCP 4o6) Transport: RFC 7341
      http://www.rfc-editor.org/rfc/rfc7341.txt
    * Source Address Validation Improvement (SAVI) Solution for DHCP: RFC 7513
      http://www.rfc-editor.org/rfc/rfc7513.txt
    * Issues and Recommendations with Multiple Stateful DHCPv6 Options: RFC 7550
      http://www.rfc-editor.org/rfc/rfc7550.txt

- SSH (Secure Shell)

  – Introduction video:
    http://www.lynda.com/Developer-Network-Administration-tutorials/What-SSH/189066/365614-4.html
  – Standard RFC (Request for Comments):

    * The Secure Shell (SSH) Protocol Assigned Numbers: RFC 4250
      http://www.rfc-editor.org/rfc/rfc4250.txt

    - The Secure Shell (SSH) Protocol Architecture: RFC 4251
      http://www.rfc-editor.org/rfc/rfc4251.txt
    - The Secure Shell (SSH) Authentication Protocol: RFC 4252
      http://www.rfc-editor.org/rfc/rfc4252.txt
    - The Secure Shell (SSH) Transport Layer Protocol: RFC 4253
      http://www.rfc-editor.org/rfc/rfc4253.txt
    - The Secure Shell (SSH) Connection Protocol: RFC 4254
      http://www.rfc-editor.org/rfc/rfc4254.txt
    - Using DNS to Securely Publish Secure Shell (SSH) Key Fingerprints: RFC 4255
      http://www.rfc-editor.org/rfc/rfc4255.txt
    - Generic Message Exchange Authentication for the Secure Shell Protocol (SSH): RFC 4256
      http://www.rfc-editor.org/rfc/rfc4256.txt
    - The Secure Shell (SSH) Session Channel Break Extension: RFC 4335
      http://www.rfc-editor.org/rfc/rfc4335.txt
    - The Secure Shell (SSH) Transport Layer Encryption Modes: RFC 4344
      http://www.rfc-editor.org/rfc/rfc4344.txt
    - Improved Arcfour Modes for the Secure Shell (SSH) Transport Layer Protocol: RFC 4345
      http://www.rfc-editor.org/rfc/rfc4345.txt
    - Diffie-Hellman Group Exchange for the Secure Shell (SSH) Transport Layer Protocol: RFC 4419
      http://www.rfc-editor.org/rfc/rfc4419.txt
    - RSA Key Exchange for the Secure Shell (SSH) Transport Layer Protocol: RFC 4432
      http://www.rfc-editor.org/rfc/rfc4432.txt
    - Generic Security Service Application Program Interface (GSS-API) Authentication and Key Exchange for the Secure Shell (SSH) Protocol: RFC 4462
      http://www.rfc-editor.org/rfc/rfc4462.txt
    - Using the NETCONF Protocol over Secure Shell (SSH): RFC 6242
      http://www.rfc-editor.org/rfc/rfc6242.txt
    - Use of the SHA-256 Algorithm with RSA, Digital Signature Algorithm (DSA), and Elliptic Curve DSA (ECDSA) in SSHFP Resource Records: RFC 6594
      http://www.rfc-editor.org/rfc/rfc6594.txt
    - SHA-2 Data Integrity Verification for the Secure Shell (SSH) Transport Layer Protocol: RFC 6668
      http://www.rfc-editor.org/rfc/rfc6668.txt

- DNS (Domain Name System)

  - Introduction video:
    https://www.youtube.com/watch?v=486d8jeCK9M

- Standard RFC (Request for Comments):

  * Automated Updates of DNS Security (DNSSEC) Trust Anchors: RFC 5011
    http://www.rfc-editor.org/rfc/rfc5011.txt
  * Extension Mechanisms for DNS (EDNS(0)): RFC 6891
    http://www.rfc-editor.org/rfc/rfc6891.txt
  * DNS Extensions to Support IP Version 6: RFC 3596
    http://www.rfc-editor.org/rfc/rfc3596.txt
  * Incremental Zone Transfer in DNS: RFC 1995
    http://www.rfc-editor.org/rfc/rfc1995.txt
  * DNS Request and Transaction Signatures (SIG(0)s): RFC 2931
    http://www.rfc-editor.org/rfc/rfc2931.txt
  * Secure Domain Name System (DNS) Dynamic Update: RFC 3007
    http://www.rfc-editor.org/rfc/rfc3007.txt
  * DNS Configuration options for Dynamic Host Configuration Protocol for IPv6 (DHCPv6): RFC 3646
    http://www.rfc-editor.org/rfc/rfc3646.txt
  * A Method for Storing IPsec Keying Material in DNS: RFC 4025
    http://www.rfc-editor.org/rfc/rfc4025.txt
  * Domain Name System (DNS) Case Insensitivity Clarification: RFC 4343
    http://www.rfc-editor.org/rfc/rfc4343.txt
  * DNS Security (DNSSEC) Experiments: RFC 4955
    http://www.rfc-editor.org/rfc/rfc4955.txt
  * DNS Name Server Identifier (NSID) Option: RFC 5001
    http://www.rfc-editor.org/rfc/rfc5001.txt
  * Measures for Making DNS More Resilient against Forged Answers: RFC 5452
    http://www.rfc-editor.org/rfc/rfc5452.txt
  * Locating IEEE 802.21 Mobility Services Using DNS: RFC 5679
    http://www.rfc-editor.org/rfc/rfc5679.txt
  * DNS SRV Resource Records for AFS: RFC 5864
    http://www.rfc-editor.org/rfc/rfc5864.txt
  * Domain Name System (DNS) Security Extensions Mapping for the Extensible Provisioning Protocol (EPP): RFC 5910
    http://www.rfc-editor.org/rfc/rfc5910.txt
  * DNS Zone Transfer Protocol (AXFR): RFC 5936
    http://www.rfc-editor.org/rfc/rfc5936.txt
  * DNS Transport over TCP - Implementation Requirements: RFC 5966
    http://www.rfc-editor.org/rfc/rfc5966.txt
  * Cryptographic Algorithm Identifier Allocation for DNSSEC: RFC 6014
    http://www.rfc-editor.org/rfc/rfc6014.txt
  * IPv6 Router Advertisement Options for DNS Configuration: RFC 6106
    http://www.rfc-editor.org/rfc/rfc6106.txt

* DNS64: DNS Extensions for Network Address Translation from IPv6 Clients to IPv4 Servers: RFC 6147
  http://www.rfc-editor.org/rfc/rfc6147.txt
* Elliptic Curve Digital Signature Algorithm (DSA) for DNSSEC: RFC 6605
  http://www.rfc-editor.org/rfc/rfc6605.txt
* Using DNS SRV to Specify a Global File Namespace with NFS Version 4: RFC 6641
  http://www.rfc-editor.org/rfc/rfc6641.txt
* DNAME Redirection in the DNS: RFC 6672
  http://www.rfc-editor.org/rfc/rfc6672.txt
* DNS Security (DNSSEC) DNSKEY Algorithm IANA Registry Updates: RFC 6725
  http://www.rfc-editor.org/rfc/rfc6725.txt
* Improved Recursive DNS Server Selection for Multi-Interfaced Nodes: RFC 6731
  http://www.rfc-editor.org/rfc/rfc6731.txt
* Multicast DNS: RFC 6762
  http://www.rfc-editor.org/rfc/rfc6762.txt
* DNS-Based Service Discovery: RFC 6763
  http://www.rfc-editor.org/rfc/rfc6763.txt
* Clarifications and Implementation Notes for DNS Security (DNSSEC): RFC 6840
  http://www.rfc-editor.org/rfc/rfc6840.txt
* DNS Certification Authority Authorization (CAA) Resource Record: RFC 6844
  http://www.rfc-editor.org/rfc/rfc6844.txt
* Applicability Statement: DNS Security (DNSSEC) DNSKEY Algorithm Implementation Status: RFC 6944
  http://www.rfc-editor.org/rfc/rfc6944.txt
* Signaling Cryptographic Algorithm Understanding in DNS Security Extensions (DNSSEC): RFC 6975
  http://www.rfc-editor.org/rfc/rfc6975.txt
* Location Information Server (LIS) Discovery Using IP Addresses and Reverse DNS: RFC 7216
  http://www.rfc-editor.org/rfc/rfc7216.txt
* Adding Acronyms to Simplify Conversations about DNS-Based Authentication of Named Entities (DANE): RFC 7218
  http://www.rfc-editor.org/rfc/rfc7218.txt
* Child-to-Parent Synchronization in DNS: RFC 7477
  http://www.rfc-editor.org/rfc/rfc7477.txt

5.2 Computing the SHA1 Hash in FTP

The task is to read a file of FTP packets from the FTP transfer of the file "reference.java". We have to read the bits, strip out the bytes corresponding to the file, calculate the SHA1 hash of those bytes, and return the hash.
Description: This file implements the Secure Hashing Algorithm 1 as defined in FIPS PUB 180-1 published April 17, 1995.

The SHA-1, produces a 160-bit message digest for a given data stream. It should take about 2^n steps to find a message with the same digest as a given message and $2^{(n/2)}$ to find any two messages with the same digest, when n is the digest size in bits. Therefore, this algorithm can serve as a means of providing a "fingerprint" for a message.

5.2.1 Algorithm Description

- Padding
  - Pad the message with a single one followed by zeros until the final block has 448 bits.
  - Append the size of the original message as an unsigned 64-bit integer
- Initialize the 5 hash blocks (h0,h1,h2,h3,h4) to the specific constants defined in the SHA1 standard.
- Hash (for each 512-bit block)
  - Allocate an 80 word array for the message schedule
    - Set the first 16 words to be the 512-bit block split into 16 words
    - The rest of the words are generated using the following algorithm
      - word[i-3] XOR word[i-8] XOR word[i-14] XOR word[i-16]
      - rotate 1 bit to the left
  - Loop 80 times doing the following (see 5.1)
    - Calculate SHAfunction() and the constants K (these are based on the current round number)
    - e=d
    - d=c
    - c=b (rotated left 30)
    - b=a
    - a=a (rotated left 5) + SHAfunction() + e + k + word[i]
  - Add a,b,c,d, and e to the hash output
- Output the concatenation (h0,h1,h2,h3,h4) which is the message digest

Portability Issues: SHA-1 is defined in terms of 32-bit "words". This code uses `<stdint.h>` (included via "sha1.h" to define 32 and 8 bit unsigned integer types. If your C compiler does not support 32 bit unsigned integers, this code is not appropriate.

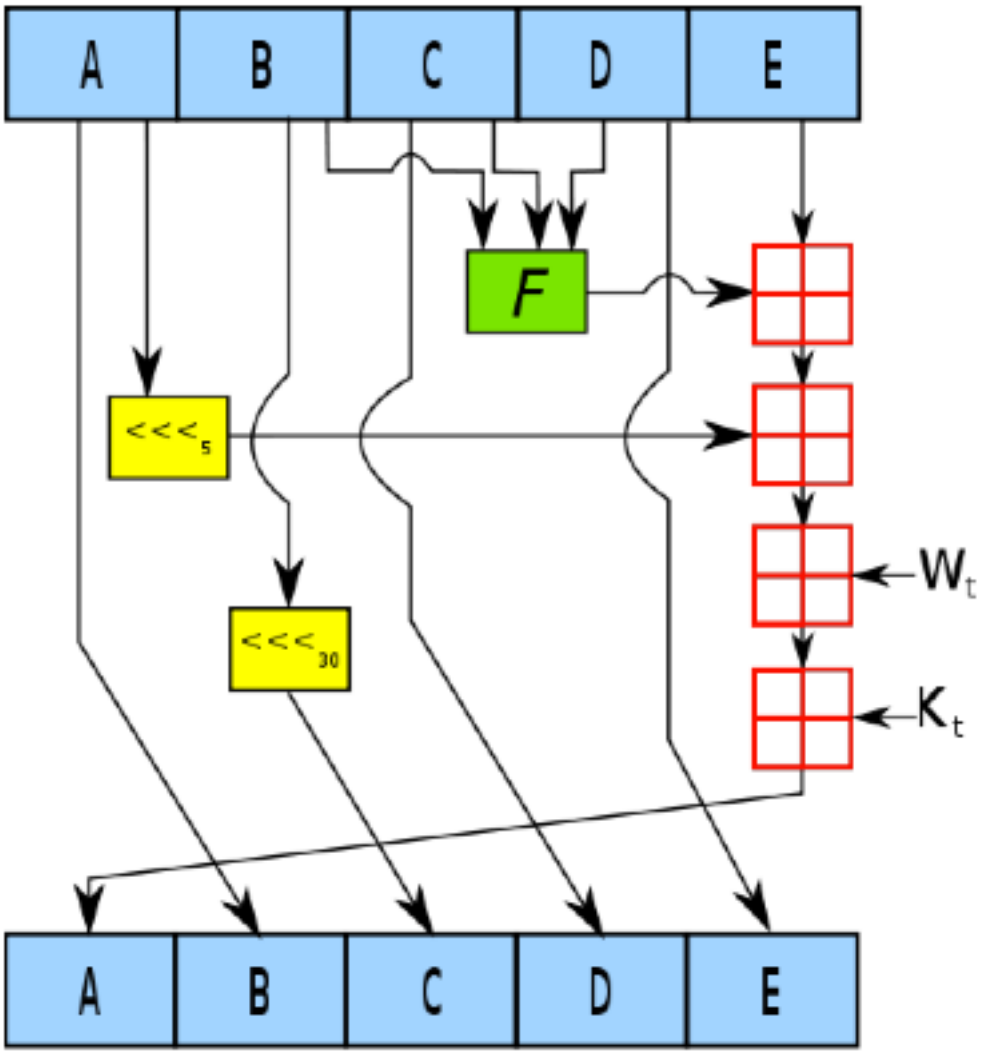


Figure 5.1: The SHA1 computation

Caveats: SHA-1 is designed to work with messages less than 2^{64} bits long. Although SHA-1 allows a message digest to be generated for messages of any number of bits less than 2^{64}, this implementation only works with messages with a length that is a multiple of the size of an 8-bit character.

See the RFC for SHA1[30] and a video[29] for details. We use the C code specified in the RFC.

— **includes** —

```
#include <stdio.h>
#include <fcntl.h>
#include <stdint.h>
```

———-

— **enums** —

```
enum
{
    shaSuccess = 0,
    shaNull,            /* Null pointer parameter */
    shaInputTooLong,    /* input data too long */
    shaStateError       /* called Input after Result */
};
```

———-

C #defines

— **defines** —

```
#define SHA1HashSize 20
#define SHA1CircularShift(bits,word) \
                (((word) << (bits)) | ((word) >> (32-(bits))))
```

———-

5.2.2 The SHA1Context struct

This structure will hold context information for the SHA-1 hashing operation

— **SHA1Context** —

```
typedef struct SHA1Context
{
 uint32_t Intermediate_Hash[SHA1HashSize/4]; /* Message Digest          */
 uint32_t Length_Low;               /* Message length in bits           */
 uint32_t Length_High;              /* Message length in bits           */
 int_least16_t Message_Block_Index; /* Index into message block array   */
 uint8_t Message_Block[64];         /* 512-bit message blocks           */
 int Computed;                      /* Is the digest computed?          */
 int Corrupted;                     /* Is the message digest corrupted? */
} SHA1Context;
```

———-

Function prototypes

— **prototypes** —

```
int SHA1Reset(  SHA1Context *);
int SHA1Input(  SHA1Context *, const uint8_t *, unsigned int);
int SHA1Result( SHA1Context *, uint8_t Message_Digest[SHA1HashSize]);
void SHA1PadMessage(SHA1Context *);
void SHA1ProcessMessageBlock(SHA1Context *);
```

5.2.3 The SHA1Reset function

The **SHA1Reset** function will initialize the SHA1Context in preparation for computing a new SHA1 message digest. It modifies the **context** structure to contain the initial values.

— **SHA1Reset** —

```
int SHA1Reset(SHA1Context *context) {
  if (!context) {
    return shaNull;
  }
  context->Length_Low             = 0;
  context->Length_High            = 0;
  context->Message_Block_Index    = 0;
  context->Intermediate_Hash[0]   = 0x67452301;  /* H0 */
  context->Intermediate_Hash[1]   = 0xEFCDAB89;  /* H1 */
  context->Intermediate_Hash[2]   = 0x98BADCFE;  /* H2 */
  context->Intermediate_Hash[3]   = 0x10325476;  /* H3 */
  context->Intermediate_Hash[4]   = 0xC3D2E1F0;  /* H4 */
  context->Computed   = 0;
  context->Corrupted  = 0;
  return shaSuccess;
}
```

5.2.4 The SHA1PadMessage function

For **SHA1PadMessage**,the message must be padded to an even 512 bits. The first padding bit must be a '1'. The last 64 bits represent the length of the original message. All bits in between should be 0. This function will pad the message according to those rules by filling the Message_Block array accordingly. It will also call the **ProcessMessageBlock** [5.2.6] function provided appropriately. When it returns, it can be assumed that the message digest has been computed.

If the current message block is too small to hold the initial padding bits and length then we will pad the block, process it, and then continue padding into a second block.

— **SHA1PadMessage** —

```
void SHA1PadMessage(SHA1Context *context) {
```

```
  if (context->Message_Block_Index > 55) {
    context->Message_Block[context->Message_Block_Index++] = 0x80;
    while(context->Message_Block_Index < 64) {
      context->Message_Block[context->Message_Block_Index++] = 0;
    }
    SHA1ProcessMessageBlock(context);
    while(context->Message_Block_Index < 56) {
      context->Message_Block[context->Message_Block_Index++] = 0;
    }
  } else {
    context->Message_Block[context->Message_Block_Index++] = 0x80;
    while(context->Message_Block_Index < 56) {
     context->Message_Block[context->Message_Block_Index++] = 0;
    }
  }
  /* Store the message length as the last 8 octets */
  context->Message_Block[56] = context->Length_High >> 24;
  context->Message_Block[57] = context->Length_High >> 16;
  context->Message_Block[58] = context->Length_High >> 8;
  context->Message_Block[59] = context->Length_High;
  context->Message_Block[60] = context->Length_Low >> 24;
  context->Message_Block[61] = context->Length_Low >> 16;
  context->Message_Block[62] = context->Length_Low >> 8;
  context->Message_Block[63] = context->Length_Low;
  SHA1ProcessMessageBlock(context);
}
```

———-

5.2.5 The SHA1Result function

The **SHA1Result** will return the 160-bit message digest into the Message_Digest array provided by the caller. NOTE: The first octet of hash is stored in the 0th element, the last octet of hash in the 19th element.

— **SHA1Result** —

```
int SHA1Result( SHA1Context *context, uint8_t Message_Digest[SHA1HashSize]) {
  int i;
  if (!context || !Message_Digest) {
    return shaNull;
  }
  if (context->Corrupted) {
    return context->Corrupted;
  }
  if (!context->Computed) {
    SHA1PadMessage(context);
    for(i=0; i<64; ++i) {
      context->Message_Block[i] = 0; /* message may be sensitive, clear it */
    }
```

```
    context->Length_Low = 0;         /* and clear length */
    context->Length_High = 0;
    context->Computed = 1;
  }
  for(i = 0; i < SHA1HashSize; ++i) {
    Message_Digest[i] =
      context->Intermediate_Hash[i>>2] >> 8 * ( 3 - ( i & 0x03 ) );
  }
  return shaSuccess;
}
```

———-

5.2.6 The SHA1ProcessMessageBlock function

The **SHA1ProcessMessageBlock** will process the next 512 bits of the message stored in the Message_Block array. Note that single character names were used because those were the names used in the publication.

— **SHA1ProcessMessageBlock** —

```
void SHA1ProcessMessageBlock(SHA1Context *context) {
  const uint32_t K[] = { 0x5A827999, 0x6ED9EBA1, 0x8F1BBCDC, 0xCA62C1D6 };
                             /* Constants defined in SHA-1  */
  int t;                     /* Loop counter                */
  uint32_t temp;             /* Temporary word value        */
  uint32_t W[80];            /* Word sequence               */
  uint32_t A, B, C, D, E;    /* Word buffers                */
  for(t = 0; t < 16; t++) {
    W[t] = context->Message_Block[t * 4] << 24;
    W[t] |= context->Message_Block[t * 4 + 1] << 16;
    W[t] |= context->Message_Block[t * 4 + 2] << 8;
    W[t] |= context->Message_Block[t * 4 + 3];
  }
  for(t = 16; t < 80; t++) {
    W[t] = SHA1CircularShift(1,W[t-3] ^ W[t-8] ^ W[t-14] ^ W[t-16]);
  }
  A = context->Intermediate_Hash[0];
  B = context->Intermediate_Hash[1];
  C = context->Intermediate_Hash[2];
  D = context->Intermediate_Hash[3];
  E = context->Intermediate_Hash[4];
  for(t = 0; t < 20; t++) {
    temp =  SHA1CircularShift(5,A) + ((B & C) | ((~B) & D)) + E + W[t] + K[0];
    E = D;
    D = C;
    C = SHA1CircularShift(30,B);
    B = A;
    A = temp;
  }
```

```
  for(t = 20; t < 40; t++) {
    temp = SHA1CircularShift(5,A) + (B ^ C ^ D) + E + W[t] + K[1];
    E = D;
    D = C;
    C = SHA1CircularShift(30,B);
    B = A;
    A = temp;
  }
  for(t = 40; t < 60; t++) {
    temp = SHA1CircularShift(5,A)+((B & C) | (B & D) | (C & D))+E+W[t]+K[2];
    E = D;
    D = C;
    C = SHA1CircularShift(30,B);
    B = A;
    A = temp;
  }
  for(t = 60; t < 80; t++) {
    temp = SHA1CircularShift(5,A) + (B ^ C ^ D) + E + W[t] + K[3];
    E = D;
    D = C;
    C = SHA1CircularShift(30,B);
    B = A;
    A = temp;
  }
  context->Intermediate_Hash[0] += A;
  context->Intermediate_Hash[1] += B;
  context->Intermediate_Hash[2] += C;
  context->Intermediate_Hash[3] += D;
  context->Intermediate_Hash[4] += E;
  context->Message_Block_Index = 0;
}
```

———-

5.2.7 The SHA1Input function

The **SHA1Input** accepts an array of octets as the next portion of the message. The **context** contains the SHA context to update. The **message_array** contains the array of characters representing the next portion of the message. The **length** is the length of the message_array.

— **SHA1Input** —

```
int SHA1Input(SHA1Context    *context,
              const uint8_t  *message_array,
              unsigned       length) {
  if (!length) {
    return shaSuccess;
  }
  if (!context || !message_array) {
    return shaNull;
```

```
  }
  if (context->Computed) {
    context->Corrupted = shaStateError;
    return shaStateError;
  }
  if (context->Corrupted) {
     return context->Corrupted;
  }
  while(length-- && !context->Corrupted) {
    context->Message_Block[context->Message_Block_Index++] =
                  (*message_array & 0xFF);
    context->Length_Low += 8;
    if (context->Length_Low == 0) {
      context->Length_High++;
      if (context->Length_High == 0) {
        context->Corrupted = 1;   /* Message is too long */
      }
    }
    if (context->Message_Block_Index == 64) {
      SHA1ProcessMessageBlock(context);
    }
    message_array++;
  }
  return shaSuccess;
}
```

———-

5.2.8 The processFile function

The **processFile** function assumes that the files are **open** for **binary** reading and writing. It copies the bytes. In a successful copy, **outcount** will end up 0.

— **processfile** —

```
int processfile(FILE* input, FILE* output) {
  unsigned char buffer[1024];
  size_t incount;
  size_t outcount;
  do {
    incount = fread(buffer,sizeof(unsigned char),sizeof(buffer),input);
    if (incount) {
      outcount = fwrite(buffer,1,incount,output);
    } else {
      outcount = 0;
    }
  } while ((incount > 0) && (incount == outcount));
  return outcount;
}
```

———-

5.2.9 The RFC test set

The **RFCtest** function runs the test code specified in RFC 3174[30]. This will exercise the SHA-1 code performing the three tests documented in FIPS PUB 180-1 plus one which calls SHA1Input with an exact multiple of 512 bits, plus a few error test checks.

— **rfctest.c** —

```
#include <string.h>
\getchunk{includes}
\getchunk{enums}
\getchunk{defines}
\getchunk{SHA1Context}
\getchunk{prototypes}
\getchunk{SHA1Reset}
\getchunk{SHA1PadMessage}
\getchunk{SHA1Result}
\getchunk{SHA1ProcessMessageBlock}
\getchunk{SHA1Input}

/* Define patterns for testing */
#define TEST1   "abc"
#define TEST2a  "abcdbcdecdefdefgefghfghighijhi"
#define TEST2b  "jkijkljklmklmnlmnomnopnopq"
#define TEST2   TEST2a TEST2b
#define TEST3   "a"
#define TEST4a  "01234567012345670123456701234567"
#define TEST4b  "01234567012345670123456701234567"
/* an exact multiple of 512 bits */
#define TEST4   TEST4a TEST4b
char *testarray[4] = { TEST1, TEST2, TEST3, TEST4 };
long int repeatcount[4] = { 1, 1, 1000000, 10 };
char *resultarray[4] = {
    "A9 99 3E 36 47 06 81 6A BA 3E 25 71 78 50 C2 6C 9C D0 D8 9D",
    "84 98 3E 44 1C 3B D2 6E BA AE 4A A1 F9 51 29 E5 E5 46 70 F1",
    "34 AA 97 3C D4 C4 DA A4 F6 1E EB 2B DB AD 27 31 65 34 01 6F",
    "DE A3 56 A2 CD DD 90 C7 A7 EC ED C5 EB B5 63 93 4F 46 04 52"
};

int main() {
  SHA1Context sha;
  int i, j, err;
  uint8_t Message_Digest[20];
  for(j = 0; j < 4; ++j) {
    printf( "\nTest %d: %ld, '%s'\n", j+1, repeatcount[j], testarray[j]);
    err = SHA1Reset(&sha);
    if (err) {
      fprintf(stderr, "SHA1Reset Error %d.\n", err );
      break; /* out of for j loop */
```

```
    }
    for(i = 0; i < repeatcount[j]; ++i) {
      err = SHA1Input(&sha,
                      (const unsigned char *) testarray[j],
                      strlen(testarray[j]));
      if (err) {
        fprintf(stderr, "SHA1Input Error %d.\n", err );
        break;    /* out of for i loop */
      }
    }
    err = SHA1Result(&sha, Message_Digest);
    if (err) {
      fprintf(stderr,
              "SHA1Result Error %d, could not compute message digest.\n",
              err );
    } else {
      printf("\t");
      for(i = 0; i < 20 ; ++i) {
        printf("%02X ", Message_Digest[i]);
      }
      printf("\n");
    }
    printf("Should match:\n");
    printf("\t%s\n", resultarray[j]);
  }
  /* Test some error returns */
  err = SHA1Input(&sha,(const unsigned char *) testarray[1], 1);
  printf ("\nError %d. Should be %d.\n", err, shaStateError );
  err = SHA1Reset(0);
  printf ("\nError %d. Should be %d.\n", err, shaNull );
  return 0;
}
```

———-

5.2.10 The main function

The **main** function opens the file, processes it, and exits. This is the command line entry purely for testing. The full program will use functions from the API.

— **sha1.c** —

```
\getchunk{includes}
\getchunk{enums}
\getchunk{defines}
\getchunk{SHA1Context}
\getchunk{prototypes}
\getchunk{SHA1Reset}
\getchunk{SHA1PadMessage}
\getchunk{SHA1Result}
```

```
\getchunk{SHA1ProcessMessageBlock}
\getchunk{SHA1Input}
\getchunk{processfile}

int main(int argc, char *argv[]) {
  FILE *input;
  FILE *output;
  int outcount = 0;
  if (argc != 3 || strcmp(argv[1],"--help") == 0) {
    printf("sha1 inputFilename outputFilename");
  }
  if ( (input = fopen(argv[1],"rb")) == NULL) {
    printf("sha1: %s file not found\n",argv[1]);
    return -1;
  }
  if ( (output = fopen(argv[2],"wb")) == NULL) {
    printf("sha1: could not open output file %s\n",argv[2]);
    return -2;
  }
  if ( (outcount = processfile(input,output)) != 0) {
    printf("sha1: binary copy from %s to %s failed\n",argv[1],argv[2]);
    return outcount;
  }
  if (fclose(output)) {
    printf("sha1: could not close %s\n",argv[2]);
    return -3;
  }
  if (fclose(input)) {
    printf("sha1: could not close %s\n",argv[1]);
    return -4;
  }
  return 0;
}
```

———-

Chapter 6

FTP Details

In this part, upon the two-ubuntu LAN that we built previously, we use FTP (File transfer protocol) to transfer a 7353 bytes file from host to server. And using Wireshark, I will give a detailed analysis on how the ftp files break into packets and into bits.

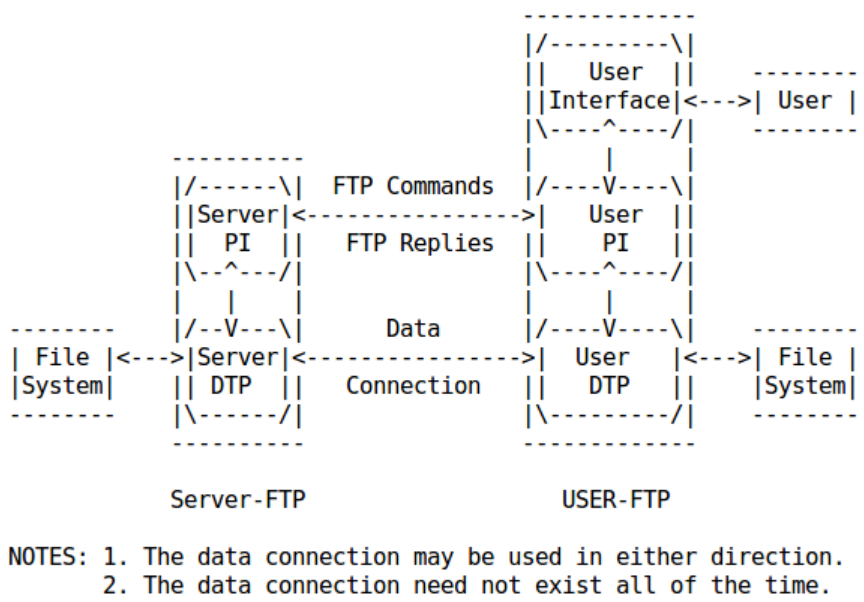


Figure 6.1: The FTP model

As can be seen in Figure 6.1, the data connection is established between the server DTP (data transfer process) and the user DTP, as for ftp commands and replies, they are transfered between server PI (protocol interpreter) and user PI.

Figure 6.2 shows a typical ftp data connection establishment.

No	Time	Protocol	Source	source port uni	Destinatior	dest port unr	Leng	Info
1	0.0000000	FTP	192.168.1.1	45273	192.168.1.2	21	74	Request: TYPE I
2	0.0010320	FTP	192.168.1.2	21	192.168.1.1	45273	97	Response: 200 Switching to Binary mode.
3	0.0012420	FTP	192.168.1.1	45273	192.168.1.2	21	92	Request: PORT 192,168,1,1,235,197
4	0.0018850	FTP	192.168.1.2	21	192.168.1.1	45273	117	Response: 200 PORT command successful. Consider
5	0.0020470	FTP	192.168.1.1	45273	192.168.1.2	21	87	Request: RETR Annotator.java

Figure 6.2: FTP data connection establishment

1. host request server for connection.
2. server responses code 200, meaning that connection permmitted.
3. and port 179,6 (45830) is to be used
4. use PASV, a mode where the client initiates the data connection.
5. ready to return the aimed file Annotator.java.

No	Time	Protocol	Source	source port uni	Destinatior	dest port unr	Leng	Info
6	0.0029170	TCP	192.168.1.2	20	192.168.1.1	60357	74	ftp-data > 60357 [SYN] Seq=0 Win=14600 Len=0 MSS
7	0.0030170	TCP	192.168.1.1	60357	192.168.1.2	20	74	60357 > ftp-data [SYN, ACK] Seq=0 Ack=1 Win=289
8	0.0031970	TCP	192.168.1.2	20	192.168.1.1	60357	66	ftp-data > 60357 [ACK] Seq=1 Ack=1 Win=14624 Le

Figure 6.3: A 3-way TCP handshake

Figure 6.3 is a typical 3-way-hand-shaking TCP, to synthesize and establish a reliable connection.

No	Time	Protocol	Source	source port uni	Destinatior	dest port unr	Leng	Info
9	0.0033710	FTP	192.168.1.2	21	192.168.1.1	45273	140	Response: 150 Opening BINARY mode data connecti

Figure 6.4: File status okay, open data connection

Figure 6.4 shows that, code 150 means "File status okay; about to open data connection."

No	Time	Protocol	Source	source port uni	Destinatior	dest port unr	Leng	Info
10	0.0036080	FTP-DATA	192.168.1.2	20	192.168.1.1	60357	1514	FTP Data: 1448 bytes
11	0.0036730	TCP	192.168.1.1	60357	192.168.1.2	20	66	60357 > ftp-data [ACK] Seq=1 Ack=1449 Win=31872
12	0.0037260	FTP-DATA	192.168.1.2	20	192.168.1.1	60357	1514	FTP Data: 1448 bytes
13	0.0037630	TCP	192.168.1.1	60357	192.168.1.2	20	66	60357 > ftp-data [ACK] Seq=1 Ack=2897 Win=34816
14	0.0038320	FTP-DATA	192.168.1.2	20	192.168.1.1	60357	1266	FTP Data: 1200 bytes
15	0.0038720	FTP-DATA	192.168.1.2	20	192.168.1.1	60357	1514	FTP Data: 1448 bytes
16	0.0039390	TCP	192.168.1.1	60357	192.168.1.2	20	66	60357 > ftp-data [ACK] Seq=1 Ack=4097 Win=37760
17	0.0039740	TCP	192.168.1.1	60357	192.168.1.2	20	66	60357 > ftp-data [ACK] Seq=1 Ack=5545 Win=40576
18	0.0040810	FTP-DATA	192.168.1.2	20	192.168.1.1	60357	1875	FTP Data: 1809 bytes
19	0.0041710	TCP	192.168.1.1	60357	192.168.1.2	20	66	60357 > ftp-data [ACK] Seq=1 Ack=7355 Win=44288
20	0.0042470	TCP	192.168.1.1	60357	192.168.1.2	20	66	60357 > ftp-data [FIN, ACK] Seq=1 Ack=7355 Win=
21	0.0044330	TCP	192.168.1.2	20	192.168.1.1	60357	66	ftp-data > 60357 [ACK] Seq=7355 Ack=2 Win=14624
22	0.0048060	FTP	192.168.1.2	21	192.168.1.1	45273	90	Response: 226 Transfer complete.

Figure 6.5: File transfer

In Figure 6.5 we come to the file transfers, we can see that the files are transferred in several parts, and after each part of data transferred into user, user would send an ACK (acknowledgement) back to server, meaning that the user received the data successfully. At

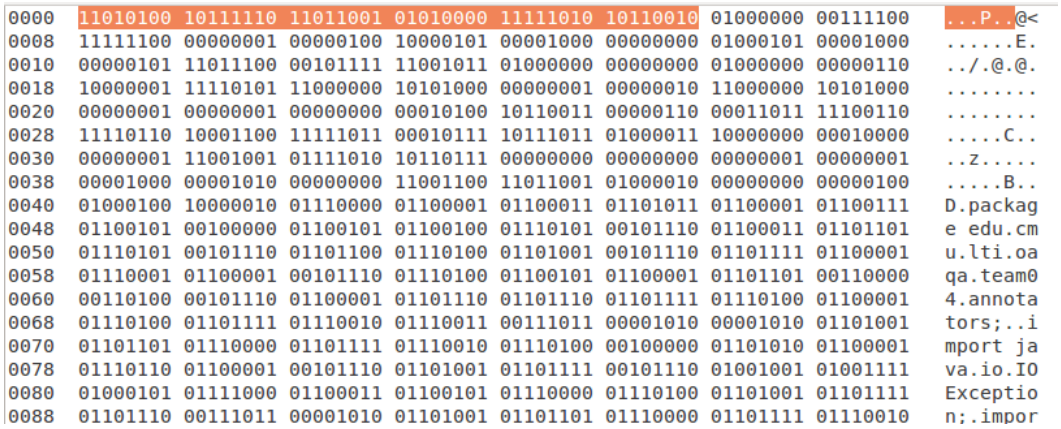


Figure 6.6: An FTP data packet

the end, code 226 means "Closing data connection. Requested file action successful (for example, file transfer or file abort)."

Figure 6.6 shows one of the ftp-data packet, where bits of the packet can be seen.

First, how can we know if the packet is the ftp-data packet? We can check the source port (20 as ftp data) and destination port, and in the meantime check if there are bits after 66 bytes. (We will see the code inplementation of this soon)

Thus, similarly, for every ftp-data packet, we can grab those bits of data from the 66 bytes of the packet to the end.

Now let's look into the bits of one of the ftp-data packet of the file (Annotator.java).

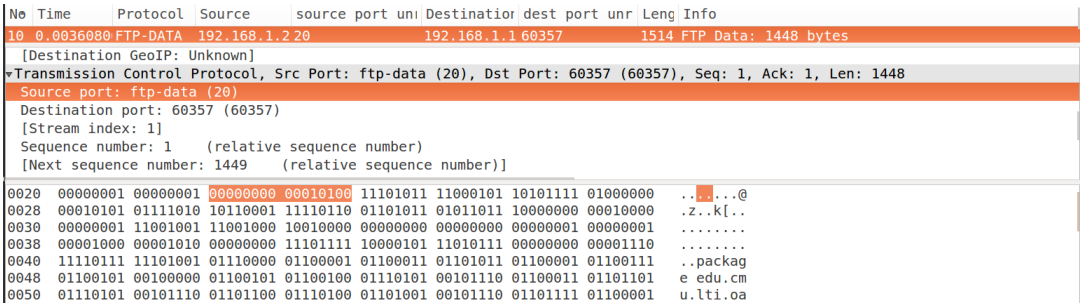


Figure 6.7: Details

Figure 6.7, figure 6.8, figure 6.9, and figure 6.10 show the details for a packet.

For each packet:

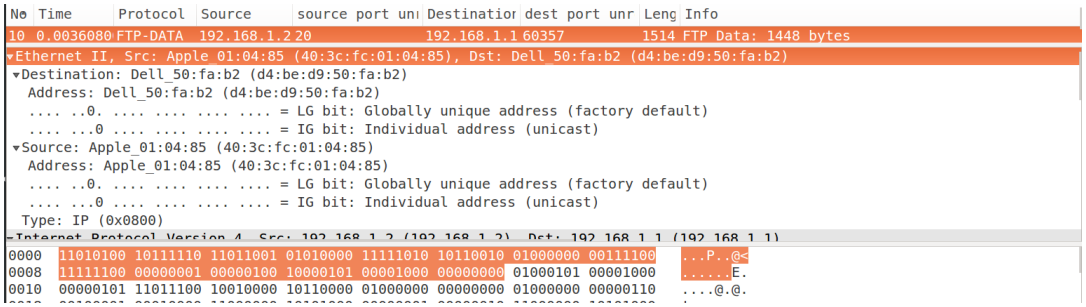


Figure 6.8: Bit level details

1. **bytes 0-5** first 6 bytes are user mac address (d4:be:d9:50:fa:b2 here)

   — **get dest mac addr** —

   ```
   /*got to write this*/
   ```

   ————-

   bytes 6-11 (6) bytes are server mac address (40:3c:fc:01:04:85),
   bytes 12-13 (2) bytes are IP (0X0800).

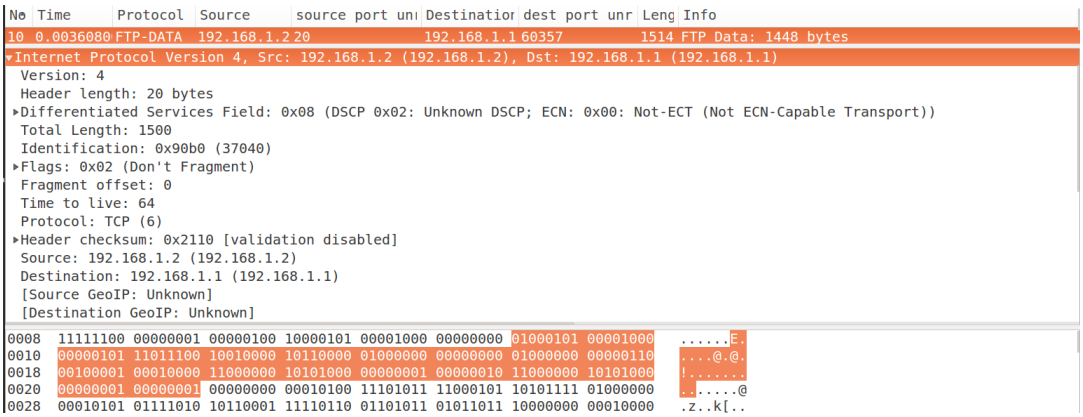


Figure 6.9: More bit level details

2. **byte 14** is header length (20),

   byte 15 is the tag byte,

   bytes 16-17 (2) bytes are total length of data transferred (1500),

   bytes 18-19 (2) bytes are identification (0x2fcb $->$ 12235),

   bytes 20-21 (2) bytes are fragment offset (0),

   byte 22 is time to live (64),

   byte 23 is protocol used (6 $->$ TCP),

   bytes 24-25 (2) bytes are header checksum (0x81f5 $->$ validation disabled),

   bytes 26-29 (4) bytes are source GeoIP (unknown),

   bytes 30-33 (4) bytes are destination GeoIP (unknown).

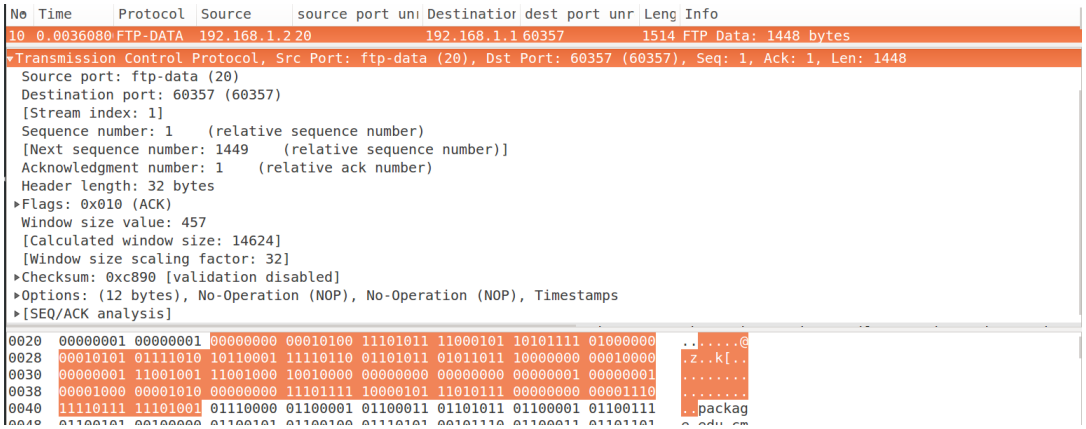


Figure 6.10: More bit level details

3. **bytes 34-35** (2) bytes are source port (20 − > ftp-data port),

   bytes 36-37 (2) bytes are destination port (45830),

   bytes 38-41 (4) bytes are sequence number (1),

   bytes 42-45 (4) bytes are acknowledgment number (1),

   bytes 46-47 (2) bytes are flags (0x010),

   bytes 48-49 (2) bytes are window size value and scaling factor,

   bytes 50-51 (2) bytes are checksum (0x7ab7 − > validation disabled),

   bytes 52-61 all belong to TCP,

   bytes 62-65 (4) bytes are timestamp echo reply (279682).

4. then we see our data (1448 bytes), which takes a large part of the packet.

Thus, this analysis gives us the hint of how to abstract the bits of the file out of the packets flow.

A packet analyzer (also known as a network analyzer, protocol analyzer or packet sniffer, for particular types of networks, an Ethernet sniffer or wireless sniffer) is a computer program or piece of computer hardware that can intercept and log traffic that passes over a digital network or part of a network. As data streams flow across the network, the sniffer captures each packet and, if needed, decodes the packet's raw data, showing the values of various fields in the packet, and analyzes its content according to the appropriate RFC or other specifications. [39] Wireshark for example is the most popular packet sniffer out there and is available for all platforms. Its gui based and very easy to use.

In this chapter we are going to talk about how to code and make our own packet sniffer in C and on the linux platform.

Note that it sniffs only incoming packets.

— **includes** —

```
#include<stdio.h> //For standard things
#include<stdlib.h>    //malloc
#include<string.h>    //memset
//can get
#include<netinet/tcp.h>   //Provides declarations for tcp header
//can get
#include<netinet/ip.h>    //Provides declarations for ip header
#include<sys/socket.h>
#include<arpa/inet.h>
```

———-

— About the sockaddrin struct —

```
struct sockaddr_in{
  short sin_family;
  unsigned short sin_port;
  IN_ADDR sin_addr;
  char sin_zero[8];
};
members in struct:
sin_family
    Address family; must be AF_INET.
sin_port
    Internet Protocol (IP) port.
sin_addr
    IP address in network byte order.
sin_zero
    Padding to make structure the same size as SOCKADDR.
```

———-

— globalVs —

```
int sock_raw;
FILE *logfile;
int tcp=0,others=0,total=0,i,j;
struct sockaddr_in source,dest;
```

———-

Function prototypes

— prototypes —

```
void ProcessPacket(unsigned char* , int);
void printipheader(unsigned char* , int);
void printtcppacket(unsigned char* , int);
void PrintData (unsigned char* , int);
```

———-

6.0.11 The ProcessPacket function

In this ProcessPacket function, we:

1. get the IP header part of the packet. 2. check the protocol and see if it's tcp in this case 3. if it's tcp, then print the packet in tcp format

— **ProcessPacket** —

```
void ProcessPacket(unsigned char* buffer, int size)
{
    //Get the IP Header part of this packet
    struct iphdr *iph = (struct iphdr*)buffer;
    ++total;
    switch (iph->protocol) //Check the Protocol and do accordingly...
    {
        case 6:  //TCP Protocol
            ++tcp;
            printtcppacket(buffer , size);
            break;

        default: //Some Other Protocol like ARP etc.
            ++others;
            break;
    }
    printf("TCP : %d   Others : %d   Total : %d\r",tcp,others,total);
}
```

———-

6.0.12 The printipheader function

For **printipheader**,

— **printipheader** —

```
void printipheader(unsigned char* Buffer, int Size)
{
    unsigned short iphdrlen;

    struct iphdr *iph = (struct iphdr *)Buffer;
    iphdrlen =iph->ihl*4;

    memset(&source, 0, sizeof(source));
    source.sin_addr.s_addr = iph->saddr;

    memset(&dest, 0, sizeof(dest));
    dest.sin_addr.s_addr = iph->daddr;

    fprintf(logfile,"\n");
```

```
    fprintf(logfile,"IP Header\n");
    fprintf(logfile,"   |-IP Version        : %d\n",(unsigned int)iph->version);
    fprintf(logfile,"   |-IP Header Length  : %d DWORDS or %d Bytes\n",(unsigned int)iph->ihl,((unsigned int
    fprintf(logfile,"   |-Type Of Service   : %d\n",(unsigned int)iph->tos);
    fprintf(logfile,"   |-IP Total Length   : %d  Bytes(Size of Packet)\n",ntohs(iph->tot_len));
    fprintf(logfile,"   |-Identification    : %d\n",ntohs(iph->id));
    //fprintf(logfile,"   |-Reserved ZERO Field   : %d\n",(unsigned int)iphdr->ip_reserved_zero);
    //fprintf(logfile,"   |-Dont Fragment Field   : %d\n",(unsigned int)iphdr->ip_dont_fragment);
    //fprintf(logfile,"   |-More Fragment Field   : %d\n",(unsigned int)iphdr->ip_more_fragment);
    fprintf(logfile,"   |-TTL      : %d\n",(unsigned int)iph->ttl);
    fprintf(logfile,"   |-Protocol : %d\n",(unsigned int)iph->protocol);
    fprintf(logfile,"   |-Checksum : %d\n",ntohs(iph->check));
    fprintf(logfile,"   |-Source IP        : %s\n",inet_ntoa(source.sin_addr));
    fprintf(logfile,"   |-Destination IP   : %s\n",inet_ntoa(dest.sin_addr));
}
```

———-

6.0.13 The printtcppacket function

The **printtcppacket** will

— **printtcppacket** —

```
void printtcppacket(unsigned char* Buffer, int Size)
{
    unsigned short iphdrlen;

    struct iphdr *iph = (struct iphdr *)Buffer;
    iphdrlen = iph->ihl*4;

    struct tcphdr *tcph=(struct tcphdr*)(Buffer + iphdrlen);

    fprintf(logfile,"\n\n**********************TCP Packet*************************\n");

    printipheader(Buffer,Size);

    fprintf(logfile,"\n");
    fprintf(logfile,"TCP Header\n");
    fprintf(logfile,"   |-Source Port      : %u\n",ntohs(tcph->source));
    fprintf(logfile,"   |-Destination Port : %u\n",ntohs(tcph->dest));
    fprintf(logfile,"   |-Sequence Number    : %u\n",ntohl(tcph->seq));
    fprintf(logfile,"   |-Acknowledge Number : %u\n",ntohl(tcph->ack_seq));
    fprintf(logfile,"   |-Header Length      : %d DWORDS or %d BYTES\n" ,(unsigned int)tcph->doff,(unsigned
    //fprintf(logfile,"   |-CWR Flag : %d\n",(unsigned int)tcph->cwr);
    //fprintf(logfile,"   |-ECN Flag : %d\n",(unsigned int)tcph->ece);
    fprintf(logfile,"   |-Urgent Flag          : %d\n",(unsigned int)tcph->urg);
    fprintf(logfile,"   |-Acknowledgement Flag : %d\n",(unsigned int)tcph->ack);
    fprintf(logfile,"   |-Push Flag            : %d\n",(unsigned int)tcph->psh);
    fprintf(logfile,"   |-Reset Flag           : %d\n",(unsigned int)tcph->rst);
```

```
    fprintf(logfile,"   |-Synchronise Flag     : %d\n",(unsigned int)tcph->syn);
    fprintf(logfile,"   |-Finish Flag          : %d\n",(unsigned int)tcph->fin);
    fprintf(logfile,"   |-Window         : %d\n",ntohs(tcph->window));
    fprintf(logfile,"   |-Checksum       : %d\n",ntohs(tcph->check));
    fprintf(logfile,"   |-Urgent Pointer : %d\n",tcph->urg_ptr);
    fprintf(logfile,"\n");
    fprintf(logfile,"                        DATA Dump                         ");
    fprintf(logfile,"\n");

    fprintf(logfile,"IP Header\n");
    PrintData(Buffer,iphdrlen);

    fprintf(logfile,"TCP Header\n");
    PrintData(Buffer+iphdrlen,tcph->doff*4);

    fprintf(logfile,"Data Payload\n");
    PrintData(Buffer + iphdrlen + tcph->doff*4 , (Size - tcph->doff*4-iph->ihl*4) );

    fprintf(logfile,"\n###########################################################");
}
```

———-

6.0.14 The PrintData function

The **PrintData** will

— **PrintData** —

```
void PrintData (unsigned char* data , int Size)
{

    for(i=0 ; i < Size ; i++)
    {
        if( i!=0 && i%16==0)   //if one line of hex printing is complete...
        {
            fprintf(logfile,"         ");
            for(j=i-16 ; j<i ; j++)
            {
                if(data[j]>=32 && data[j]<=128)
                    fprintf(logfile,"%c",(unsigned char)data[j]); //if its a number or alphabet

                else fprintf(logfile,"."); //otherwise print a dot
            }
            fprintf(logfile,"\n");
        }

        if(i%16==0) fprintf(logfile,"   ");
            fprintf(logfile," %02X",(unsigned int)data[i]);
```

```
        if( i==Size-1)  //print the last spaces
        {
            for(j=0;j<15-i%16;j++) fprintf(logfile,"   "); //extra spaces

            fprintf(logfile,"         ");

            for(j=i-i%16 ; j<=i ; j++)
            {
                if(data[j]>=32 && data[j]<=128) fprintf(logfile,"%c",(unsigned char)data[j]);
                else fprintf(logfile,".");
            }
            fprintf(logfile,"\n");
        }
    }
}
```

———-

6.0.15 ear.c

The **main** function

In the main() function we:

1. Create a raw socket, using socket() function. 2. Put it in a recvfrom loop and receive data on it, and process the recieved data. 3. close the socket after at the end.

— **ear.c** —

```
\getchunk{includes}
\getchunk{globalVs}
\getchunk{prototypes}
\getchunk{ProcessPacket}
\getchunk{printipheader}
\getchunk{printtcppacket}
\getchunk{PrintData}

int main()
{
    int saddr_size , data_size;
    struct sockaddr saddr;
    struct in_addr in;

    unsigned char *buffer = (unsigned char *)malloc(65536); //Its Big!

    logfile=fopen("log.txt","w");
    if(logfile==NULL) printf("Unable to create file.");
    printf("Starting...\n");
    //Create a raw socket that shall sniff
    sock_raw = socket(AF_INET , SOCK_RAW , IPPROTO_TCP);
```

```
    if(sock_raw < 0)
    {
        printf("Socket Error\n");
        return 1;
    }
    while(1)
    {
        saddr_size = sizeof saddr;
        //Receive a packet
        data_size = recvfrom(sock_raw , buffer , 65536 , 0 , &saddr , &saddr_size);
        if(data_size <0 )
        {
            printf("Recvfrom error , failed to get packets\n");
            return 1;
        }
        //Now process the packet
        ProcessPacket(buffer , data_size);
    }
    close(sock_raw);
    printf("Finished");
    return 0;
}
```

———-

— sample output: —

```
***********************TCP Packet*************************

IP Header
   |-IP Version        : 4
   |-IP Header Length  : 5 DWORDS or 20 Bytes
   |-Type Of Service   : 8
   |-IP Total Length   : 1500  Bytes(Size of Packet)
   |-Identification    : 1652
   |-TTL      : 64
   |-Protocol : 6
   |-Checksum : 43852
   |-Source IP        : 192.168.1.2
   |-Destination IP   : 192.168.1.1

TCP Header
   |-Source Port      : 20
   |-Destination Port : 59325
   |-Sequence Number    : 110330488
   |-Acknowledge Number : 1095205422
   |-Header Length      : 8 DWORDS or 32 BYTES
   |-Urgent Flag          : 0
   |-Acknowledgement Flag : 1
```

```
   |-Push Flag            : 0
   |-Reset Flag           : 0
   |-Synchronise Flag     : 0
   |-Finish Flag          : 0
   |-Window         : 457
   |-Checksum       : 59494
   |-Urgent Pointer : 0

                        DATA Dump
IP Header
    45 08 05 DC 06 74 40 00 40 06 AB 4C C0 A8 01 02        E....t@.@..L....
    C0 A8 01 01                                            ....
TCP Header
    00 14 E7 BD 06 93 82 78 41 47 82 2E 80 10 01 C9        .......xAG.....
    E8 66 00 00 01 01 08 0A 01 02 84 05 00 10 F6 76        .f.............v
Data Payload
    69 6D 70 6F 72 74 20 6A 61 76 61 2E 69 6F 2E 49        import java.io.I
    4F 45 78 63 65 70 74 69 6F 6E 3B 0A 69 6D 70 6F        OException;.impo
    72 74 20 6A 61 76 61 2E 75 74 69 6C 2E 41 72 72        rt java.util.Arr
    61 79 4C 69 73 74 3B 0A 69 6D 70 6F 72 74 20 6A        ayList;.import j
    61 76 61 2E 75 74 69 6C 2E 43 6F 6C 6C 65 63 74        ava.util.Collect
    69 6F 6E 3B 0A 69 6D 70 6F 72 74 20 6A 61 76 61        ion;.import java
    2E 75 74 69 6C 2E 4C 69 73 74 3B 0A 69 6D 70 6F        .util.List;.impo
    72 74 20 6F 72 67 2E 61 70 61 63 68 65 2E 63 6F        rt org.apache.co
    6D 6D 6F 6E 73 2E 63 6F 6E 66 69 67 75 72 61 74        mmons.configurat
    69 6F 6E 2E 43 6F 6E 66 69 67 75 72 61 74 69 6F        ion.Configuratio
    6E 45 78 63 65 70 74 69 6F 6E 3B 0A 69 6D 70 6F        nException;.impo
    72 74 20 6F 72 67 2E 61 70 61 63 68 65 2E 75 69        rt org.apache.ui
    6D 61 2E 55 69 6D 61 43 6F 6E 74 65 78 74 3B 0A        ma.UimaContext;.
    69 6D 70 6F 72 74 20 6F 72 67 2E 61 70 61 63 68        import org.apach
    65 2E 75 69 6D 61 2E 61 6E 61 6C 79 73 69 73 5F        e.uima.analysis_
    63 6F 6D 70 6F 6E 65 6E 74 2E 4A 43 61 73 41 6E        component.JCasAn
    6E 6F 74 61 74 6F 72 5F 49 6D 70 6C 42 61 73 65        notator_ImplBase
    3B 0A 69 6D 70 6F 72 74 20 6F 72 67 2E 61 70 61        ;.import org.apa
    63 68 65 2E 75 69 6D 61 2E 61 6E 61 6C 79 73 69        che.uima.analysi
    73 5F 65 6E 67 69 6E 65 2E 41 6E 61 6C 79 73 69        s_engine.Analysi
    73 45 6E 67 69 6E 65 50 72 6F 63 65 73 73 45 78        sEngineProcessEx
    63 65 70 74 69 6F 6E 3B 0A 69 6D 70 6F 72 74 20        ception;.import
    6F 72 67 2E 61 70 61 63 68 65 2E 75 69 6D 61 2E        org.apache.uima.
    63 61 73 2E 46 53 49 74 65 72 61 74 6F 72 3B 0A        cas.FSIterator;.
    69 6D 70 6F 72 74 20 6F 72 67 2E 61 70 61 63 68        import org.apach
    65 2E 75 69 6D 61 2E 6A 63 61 73 2E 4A 43 61 73        e.uima.jcas.JCas
    3B 0A 69 6D 70 6F 72 74 20 6F 72 67 2E 61 70 61        ;.import org.apa
    63 68 65 2E 75 69 6D 61 2E 6A 63 61 73 2E 63 61        che.uima.jcas.ca
    73 2E 46 53 4C 69 73 74 3B 0A 69 6D 70 6F 72 74        s.FSList;.import
    20 6F 72 67 2E 61 70 61 63 68 65 2E 75 69 6D 61         org.apache.uima
    2E 6A 63 61 73 2E 63 61 73 2E 53 74 72 69 6E 67        .jcas.cas.String
    4C 69 73 74 3B 0A 69 6D 70 6F 72 74 20 6F 72 67        List;.import org
    2E 61 70 61 63 68 65 2E 75 69 6D 61 2E 72 65 73        .apache.uima.res
    6F 75 72 63 65 2E 52 65 73 6F 75 72 63 65 49 6E        ource.ResourceIn
```

```
69 74 69 61 6C 69 7A 61 74 69 6F 6E 45 78 63 65        itializationExce
70 74 69 6F 6E 3B 0A 69 6D 70 6F 72 74 20 75 74        ption;.import ut
69 6C 2E 2A 3B 0A 69 6D 70 6F 72 74 20 65 64 75        il.*;.import edu
2E 63 6D 75 2E 6C 74 69 2E 6F 61 71 61 2E 62 69        .cmu.lti.oaqa.bi
6F 2E 62 69 6F 61 73 71 2E 73 65 72 76 69 63 65        o.bioasq.service
73 2E 47 6F 50 75 62 4D 65 64 53 65 72 76 69 63        s.GoPubMedServic
65 3B 0A 69 6D 70 6F 72 74 20 65 64 75 2E 63 6D        e;.import edu.cm
75 2E 6C 74 69 2E 6F 61 71 61 2E 62 69 6F 2E 62        u.lti.oaqa.bio.b
69 6F 61 73 71 2E 73 65 72 76 69 63 65 73 2E 4C        ioasq.services.L
69 6E 6B 65 64 4C 69 66 65 44 61 74 61 53 65 72        inkedLifeDataSer
76 69 63 65 52 65 73 70 6F 6E 73 65 3B 0A 69 6D        viceResponse;.im
70 6F 72 74 20 65 64 75 2E 63 6D 75 2E 6C 74 69        port edu.cmu.lti
2E 6F 61 71 61 2E 62 69 6F 2E 62 69 6F 61 73 71        .oaqa.bio.bioasq
2E 73 65 72 76 69 63 65 73 2E 4F 6E 74 6F 6C 6F        .services.Ontolo
67 79 53 65 72 76 69 63 65 52 65 73 70 6F 6E 73        gyServiceRespons
65 3B 0A 69 6D 70 6F 72 74 20 65 64 75 2E 63 6D        e;.import edu.cm
75 2E 6C 74 69 2E 6F 61 71 61 2E 62 69 6F 2E 62        u.lti.oaqa.bio.b
69 6F 61 73 71 2E 73 65 72 76 69 63 65 73 2E 50        ioasq.services.P
75 62 4D 65 64 53 65 61 72 63 68 53 65 72 76 69        ubMedSearchServi
63 65 52 65 73 70 6F 6E 73 65 3B 0A 69 6D 70 6F        ceResponse;.impo
72 74 20 65 64 75 2E 63 6D 75 2E 6C 74 69 2E 6F        rt edu.cmu.lti.o
61 71 61 2E 62 69 6F 2E 62 69 6F 61 73 71 2E 73        aqa.bio.bioasq.s
65 72 76 69 63 65 73 2E 50 75 62 4D 65 64 53 65        ervices.PubMedSe
61 72 63 68 53 65 72 76 69 63 65 52 65 73 70 6F        archServiceRespo
6E 73 65 2E 44 6F 63 75 6D 65 6E 74 3B 0A 69 6D        nse.Document;.im
70 6F 72 74 20 65 64 75 2E 63 6D 75 2E 6C 74 69        port edu.cmu.lti
2E 6F 61 71 61 2E 74 79 70 65 2E 69 6E 70 75 74        .oaqa.type.input
2E 51 75 65 73 74 69 6F 6E 3B 0A 69 6D 70 6F 72        .Question;.impor
74 20 65 64 75 2E 63 6D 75 2E 6C 74 69 2E 6F 61        t edu.cmu.lti.oa
71 61 2E 74 79 70 65 2E 6B 62 2E 43 6F 6E 63 65        qa.type.kb.Conce
70 74 3B 0A 69 6D 70 6F 72 74 20 65 64 75 2E 63        pt;.import edu.c
6D 75 2E 6C 74 69 2E 6F 61 71 61 2E 74 79 70 65        mu.lti.oaqa.type
2E 6B 62 2E 54 72 69 70 6C 65 3B 0A 0A 70 75 62        .kb.Triple;..pub
6C 69 63 20 63 6C 61 73 73 20 41 6E 6E 6F 74 61        lic class Annota
74 6F 72 20 65 78 74 65 6E 64 73 20 4A 43 61 73        tor extends JCas
41 6E 6E 6F 74 61 74 6F 72 5F 49 6D 70 6C 42 61        Annotator_ImplBa
73 65 20 7B 0A 20 20 73 74 61 74 69 63 20 47 6F        se {.  static Go
50 75 62 4D 65 64 53 65 72 76 69 63 65 20 73 65        PubMedService se
72 76 69 63 65 20 3D 20 6E 75 6C 6C 3B 0A 0A 20        rvice = null;..
20 40 4F 76 65 72 72 69 64 65 0A 20 20 70 75 62         @Override.  pub
6C 69 63 20 76 6F 69 64 20 69 6E 69 74 69 61 6C        lic void initial
69 7A 65 28 55 69 6D 61 43 6F 6E 74 65 78 74 20        ize(UimaContext
61 43 6F 6E 74 65 78 74 29 20 74 68 72 6F 77 73        aContext) throws
20 52 65 73 6F 75 72 63 65 49 6E 69 74 69 61 6C         ResourceInitial
69 7A 61 74 69 6F 6E 45 78 63 65 70 74 69 6F 6E        izationException
20 7B 0A 20 20 20 20 74 72 79 20 7B 0A 20 20 20        {.    try {.
20 20 20 47 6F 50 75 62 4D 65 64 53 65 72 76 69          GoPubMedServi
63 65 20 73 65 72 76 69 63 65 20 3D 20 6E 65 77        ce service = new
20 47 6F 50 75 62 4D 65 64 53 65 72 76 69 63 65         GoPubMedService
28 22 2E 2F 70 72 6F 6A 65 63 74 2E 70 72 6F 70        ("./project.prop
```

```
    65 72 74 69 65 73 22 29 3B 0A 20 20 20 20 7D 20         erties");.    }
    63 61 74 63 68 20 28 43 6F 6E 66 69 67 75 72 61         catch (Configura
    74 69 6F 6E 45 78 63 65 70 74 69 6F 6E 20 65 29         tionException e)
    20 7B 0A 20 20 20 20 20 20 2F 2F 20 54 4F 44 4F          {.      // TODO
    20 41 75 74 6F 2D 67 65 6E 65 72 61 74 65 64 20          Auto-generated
    63 61 74 63 68 20 62 6C 6F 63 6B 0A 20 20 20 20         catch block.
    20 20 65 2E 70 72 69 6E                                   e.prin
```

———-

— earandsha1.c —

```
#include<stdio.h> //For standard things
#include<stdlib.h>    //malloc
#include<string.h>    //memset
#include<netinet/tcp.h>   //Provides declarations for tcp header
#include<netinet/ip.h>    //Provides declarations for ip header
#include<sys/socket.h>
#include<arpa/inet.h>


/*************************/



#include <fcntl.h>
#include <stdint.h>
#include <limits.h>

enum
{
    shaSuccess = 0,
    shaNull,            /* Null pointer parameter */
    shaInputTooLong,    /* input data too long */
    shaStateError       /* called Input after Result */
};

#define SHA1HashSize 20
#define SHA1CircularShift(bits,word) \
                (((word) << (bits)) | ((word) >> (32-(bits))))


typedef struct SHA1Context
{
 uint32_t Intermediate_Hash[SHA1HashSize/4]; /* Message Digest          */
 uint32_t Length_Low;               /* Message length in bits           */
 uint32_t Length_High;              /* Message length in bits           */
 int_least16_t Message_Block_Index; /* Index into message block array   */
 uint8_t Message_Block[64];         /* 512-bit message blocks           */
 int Computed;                      /* Is the digest computed?          */
```

```
 int Corrupted;                      /* Is the message digest corrupted? */
} SHA1Context;

SHA1Context sha;
  int errr;
int m;

 uint8_t Message_Digest[20];



int SHA1Reset(  SHA1Context *);
int SHA1Input(  SHA1Context *, const uint8_t *, unsigned int);
int SHA1Result( SHA1Context *, uint8_t Message_Digest[SHA1HashSize]);
void SHA1PadMessage(SHA1Context *);
void SHA1ProcessMessageBlock(SHA1Context *);

int SHA1Reset(SHA1Context *context) {
  if (!context) {
    return shaNull;
  }
  context->Length_Low             = 0;
  context->Length_High            = 0;
  context->Message_Block_Index    = 0;
  context->Intermediate_Hash[0]   = 0x67452301;  /* H0 */
  context->Intermediate_Hash[1]   = 0xEFCDAB89;  /* H1 */
  context->Intermediate_Hash[2]   = 0x98BADCFE;  /* H2 */
  context->Intermediate_Hash[3]   = 0x10325476;  /* H3 */
  context->Intermediate_Hash[4]   = 0xC3D2E1F0;  /* H4 */
  context->Computed   = 0;
  context->Corrupted  = 0;
  return shaSuccess;
}

void SHA1PadMessage(SHA1Context *context) {
  if (context->Message_Block_Index > 55) {
    context->Message_Block[context->Message_Block_Index++] = 0x80;
    while(context->Message_Block_Index < 64) {
      context->Message_Block[context->Message_Block_Index++] = 0;
    }
    SHA1ProcessMessageBlock(context);
    while(context->Message_Block_Index < 56) {
      context->Message_Block[context->Message_Block_Index++] = 0;
    }
  } else {
    context->Message_Block[context->Message_Block_Index++] = 0x80;
    while(context->Message_Block_Index < 56) {
     context->Message_Block[context->Message_Block_Index++] = 0;
    }
  }
```

```
  /* Store the message length as the last 8 octets */
  context->Message_Block[56] = context->Length_High >> 24;
  context->Message_Block[57] = context->Length_High >> 16;
  context->Message_Block[58] = context->Length_High >> 8;
  context->Message_Block[59] = context->Length_High;
  context->Message_Block[60] = context->Length_Low >> 24;
  context->Message_Block[61] = context->Length_Low >> 16;
  context->Message_Block[62] = context->Length_Low >> 8;
  context->Message_Block[63] = context->Length_Low;
  SHA1ProcessMessageBlock(context);
}

int SHA1Result( SHA1Context *context, uint8_t Message_Digest[SHA1HashSize]) {
  int i;
  if (!context || !Message_Digest) {
    return shaNull;
  }
  if (context->Corrupted) {
    return context->Corrupted;
  }
  if (!context->Computed) {
    SHA1PadMessage(context);
    for(i=0; i<64; ++i) {
      context->Message_Block[i] = 0; /* message may be sensitive, clear it */
    }
    context->Length_Low = 0;         /* and clear length */
    context->Length_High = 0;
    context->Computed = 1;
  }
  for(i = 0; i < SHA1HashSize; ++i) {
    Message_Digest[i] =
      context->Intermediate_Hash[i>>2] >> 8 * ( 3 - ( i & 0x03 ) );
  }
  return shaSuccess;
}

void SHA1ProcessMessageBlock(SHA1Context *context) {
  const uint32_t K[] = { 0x5A827999, 0x6ED9EBA1, 0x8F1BBCDC, 0xCA62C1D6 };
                            /* Constants defined in SHA-1  */
  int t;                    /* Loop counter                */
  uint32_t temp;            /* Temporary word value        */
  uint32_t W[80];           /* Word sequence               */
  uint32_t A, B, C, D, E;   /* Word buffers                */
  for(t = 0; t < 16; t++) {
    W[t] = context->Message_Block[t * 4] << 24;
    W[t] |= context->Message_Block[t * 4 + 1] << 16;
    W[t] |= context->Message_Block[t * 4 + 2] << 8;
    W[t] |= context->Message_Block[t * 4 + 3];
  }
  for(t = 16; t < 80; t++) {
```

```
    W[t] = SHA1CircularShift(1,W[t-3] ^ W[t-8] ^ W[t-14] ^ W[t-16]);
  }
  A = context->Intermediate_Hash[0];
  B = context->Intermediate_Hash[1];
  C = context->Intermediate_Hash[2];
  D = context->Intermediate_Hash[3];
  E = context->Intermediate_Hash[4];
  for(t = 0; t < 20; t++) {
    temp =  SHA1CircularShift(5,A) + ((B & C) | ((~B) & D)) + E + W[t] + K[0];
    E = D;
    D = C;
    C = SHA1CircularShift(30,B);
    B = A;
    A = temp;
  }
  for(t = 20; t < 40; t++) {
    temp = SHA1CircularShift(5,A) + (B ^ C ^ D) + E + W[t] + K[1];
    E = D;
    D = C;
    C = SHA1CircularShift(30,B);
    B = A;
    A = temp;
  }
  for(t = 40; t < 60; t++) {
    temp = SHA1CircularShift(5,A)+((B & C) | (B & D) | (C & D))+E+W[t]+K[2];
    E = D;
    D = C;
    C = SHA1CircularShift(30,B);
    B = A;
    A = temp;
  }
  for(t = 60; t < 80; t++) {
    temp = SHA1CircularShift(5,A) + (B ^ C ^ D) + E + W[t] + K[3];
    E = D;
    D = C;
    C = SHA1CircularShift(30,B);
    B = A;
    A = temp;
  }
  context->Intermediate_Hash[0] += A;
  context->Intermediate_Hash[1] += B;
  context->Intermediate_Hash[2] += C;
  context->Intermediate_Hash[3] += D;
  context->Intermediate_Hash[4] += E;
  context->Message_Block_Index = 0;
}

int SHA1Input(SHA1Context    *context,
              const uint8_t  *message_array,
              unsigned       length) {
```

```
  if (!length) {
    return shaSuccess;
  }
  if (!context || !message_array) {
    return shaNull;
  }
  if (context->Computed) {
    context->Corrupted = shaStateError;
    return shaStateError;
  }
  if (context->Corrupted) {
     return context->Corrupted;
  }
  while(length-- && !context->Corrupted) {
    context->Message_Block[context->Message_Block_Index++] =
                  (*message_array & 0xFF);
    context->Length_Low += 8;
    if (context->Length_Low == 0) {
      context->Length_High++;
      if (context->Length_High == 0) {
        context->Corrupted = 1;   /* Message is too long */
      }
    }
    if (context->Message_Block_Index == 64) {
      SHA1ProcessMessageBlock(context);
    }
    message_array++;
  }
  return shaSuccess;
}


int lengthOfU(unsigned char * str)
{
    int i = 0;

    while(*(str++)){
     i++;
     if(i == INT_MAX)
         return -1;
    }

    return i;
}



void callsha1(unsigned char *testarray, int Size) {
/*
int tt=0;
```

```
for(tt=0;tt<Size;tt++) {

printf("%02X", testarray[tt]);
}
printf("\n");
*/



  //int m;
  //uint8_t Message_Digest[20];



   // errr = SHA1Reset(&sha);


    errr = SHA1Input(&sha,
                     (const unsigned char *) testarray,
                     Size);


    //errr = SHA1Result(&sha, Message_Digest);
/*
      printf("\n");
      for(m = 0; m < 20 ; ++m) {
        printf("%02X ", Message_Digest[m]);
      }
      printf("\n");*/
    printf("One done!\n");

}



/***************************/



#ifdef __BIG_ENDIAN__
# define SHA_BIG_ENDIAN
#elif defined __LITTLE_ENDIAN__
/* override */
#elif defined __BYTE_ORDER
# if __BYTE_ORDER__ ==  __ORDER_BIG_ENDIAN__
# define SHA_BIG_ENDIAN
# endif
#else // ! defined __LITTLE_ENDIAN__
# include <endian.h> // machine/endian.h
# if __BYTE_ORDER__ ==  __ORDER_BIG_ENDIAN__
```

```
#  define SHA_BIG_ENDIAN
# endif
#endif


/* header */

#define HASH_LENGTH 20
#define BLOCK_LENGTH 64

typedef struct sha1nfo {
uint32_t buffer[BLOCK_LENGTH/4];
uint32_t state[HASH_LENGTH/4];
uint32_t byteCount;
uint8_t bufferOffset;
uint8_t keyBuffer[BLOCK_LENGTH];
uint8_t innerHash[HASH_LENGTH];
} sha1nfo;

uint32_t aaaa;
sha1nfo ssss;

/* public API - prototypes - TODO: doxygen*/

/**
 */
void sha1_init(sha1nfo *s);
/**
 */
void sha1_writebyte(sha1nfo *s, uint8_t data);
/**
 */
void sha1_write(sha1nfo *s, const char *data, size_t len);
/**
 */
uint8_t* sha1_result(sha1nfo *s);
/**
 */


/* code */
#define SHA1_K0  0x5a827999
#define SHA1_K20 0x6ed9eba1
#define SHA1_K40 0x8f1bbcdc
#define SHA1_K60 0xca62c1d6

void sha1_init(sha1nfo *s) {
s->state[0] = 0x67452301;
s->state[1] = 0xefcdab89;
s->state[2] = 0x98badcfe;
```

```
s->state[3] = 0x10325476;
s->state[4] = 0xc3d2e1f0;
s->byteCount = 0;
s->bufferOffset = 0;
}

uint32_t sha1_rol32(uint32_t number, uint8_t bits) {
return ((number << bits) | (number >> (32-bits)));
}

void sha1_hashBlock(sha1nfo *s) {
uint8_t i;
uint32_t a,b,c,d,e,t;

a=s->state[0];
b=s->state[1];
c=s->state[2];
d=s->state[3];
e=s->state[4];
for (i=0; i<80; i++) {
if (i>=16) {
t = s->buffer[(i+13)&15] ^ s->buffer[(i+8)&15] ^ s->buffer[(i+2)&15] ^ s->buffer[i&15];
s->buffer[i&15] = sha1_rol32(t,1);
}
if (i<20) {
t = (d ^ (b & (c ^ d))) + SHA1_K0;
} else if (i<40) {
t = (b ^ c ^ d) + SHA1_K20;
} else if (i<60) {
t = ((b & c) | (d & (b | c))) + SHA1_K40;
} else {
t = (b ^ c ^ d) + SHA1_K60;
}
t+=sha1_rol32(a,5) + e + s->buffer[i&15];
e=d;
d=c;
c=sha1_rol32(b,30);
b=a;
a=t;
}
s->state[0] += a;
s->state[1] += b;
s->state[2] += c;
s->state[3] += d;
s->state[4] += e;
}

void sha1_addUncounted(sha1nfo *s, uint8_t data) {
uint8_t * const b = (uint8_t*) s->buffer;
#ifdef SHA_BIG_ENDIAN
```

```
b[s->bufferOffset] = data;
#else
b[s->bufferOffset ^ 3] = data;
#endif
s->bufferOffset++;
if (s->bufferOffset == BLOCK_LENGTH) {
sha1_hashBlock(s);
s->bufferOffset = 0;
}
}

void sha1_writebyte(sha1nfo *s, uint8_t data) {
++s->byteCount;
sha1_addUncounted(s, data);
}

void sha1_write(sha1nfo *s, const char *data, size_t len) {
for (;len--;) sha1_writebyte(s, (uint8_t) *data++);
}

void sha1_pad(sha1nfo *s) {
// Implement SHA-1 padding (fips180-2 5.1.1)

// Pad with 0x80 followed by 0x00 until the end of the block
sha1_addUncounted(s, 0x80);
while (s->bufferOffset != 56) sha1_addUncounted(s, 0x00);

// Append length in the last 8 bytes
sha1_addUncounted(s, 0); // We're only using 32 bit lengths
sha1_addUncounted(s, 0); // But SHA-1 supports 64 bit lengths
sha1_addUncounted(s, 0); // So zero pad the top bits
sha1_addUncounted(s, s->byteCount >> 29); // Shifting to multiply by 8
sha1_addUncounted(s, s->byteCount >> 21); // as SHA-1 supports bitstreams as well as
sha1_addUncounted(s, s->byteCount >> 13); // byte.
sha1_addUncounted(s, s->byteCount >> 5);
sha1_addUncounted(s, s->byteCount << 3);
}

uint8_t* sha1_result(sha1nfo *s) {
// Pad to complete the last block
sha1_pad(s);

#ifndef SHA_BIG_ENDIAN
// Swap byte order back
int i;
for (i=0; i<5; i++) {
s->state[i]=
  (((s->state[i])<<24)& 0xff000000)
| (((s->state[i])<<8) & 0x00ff0000)
| (((s->state[i])>>8) & 0x0000ff00)
```

```
| (((s->state[i])>>24)& 0x000000ff);
}
#endif

// Return pointer to hash (20 characters)
return (uint8_t*) s->state;
}



/* self-test */


void printHash(uint8_t* hash) {
int i;
for (i=0; i<20; i++) {
printf("%02x", hash[i]);
}
printf("\n");
}



void callsha11(unsigned char *testarray, int Size) {



// SHA tests
printf("Test: FIPS 180-2 C.1 and RFC3174 7.3 TEST1\n");
printf("Expect:a9993e364706816aba3e25717850c26c9cd0d89d\n");
printf("Result:");
//sha1_init(&ssss);
//sha1_write(&ssss, testarray, Size);
printf("\n");
int tt=0;
for(tt=0;tt<Size;tt++){
sha1_writebyte(&ssss, testarray[tt]);
//printf("%c",testarray[tt]);
}
//printHash(sha1_result(&ssss));
printf("\n");
}




/*************************/


void ProcessPacket(unsigned char* , int);
```

```
void printipheader(unsigned char* , int);
void printtcppacket(unsigned char* , int);
void PrintData (unsigned char* , int);

int sock_raw;
FILE *logfile;
int tcp=0,others=0,total=0,i,j;
int count=0;

struct sockaddr_in source,dest;


int main()
{
    int saddr_size , data_size;
    struct sockaddr saddr;
    struct in_addr in;

    //create a buffer to hold large amount of data
    unsigned char *buffer = (unsigned char *)malloc(65536);

    logfile=fopen("log.txt","w");
    if(logfile==NULL) printf("Unable to create file.");
    printf("Starting...\n");
    //Create a raw socket that shall sniff
    sock_raw = socket(AF_INET , SOCK_RAW , IPPROTO_TCP);
    if(sock_raw < 0)
    {
        printf("Socket Error\n");
        return 1;
    }

sha1_init(&ssss);

  errr = SHA1Reset(&sha);


    while(1)
    {
        saddr_size = sizeof saddr;
        //Receive a packet
        data_size = recvfrom(sock_raw , buffer , 65536 , 0 , &saddr , &saddr_size);
        if(data_size <0 )
        {
            printf("Recvfrom error , failed to get packets\n");
            return 1;
        }
        //Now process the packet
        ProcessPacket(buffer , data_size);
//printf("%d\n",countttt);
```

```
if(count>4) goto f1;
    }

    close(sock_raw);
f1:
printHash(sha1_result(&ssss));


//errr = SHA1Result(&sha, Message_Digest);

      /*printf("\n");
      for(m = 0; m < 20 ; ++m) {
        printf("%02X ", Message_Digest[m]);
      }
      printf("\n");*/

    printf("Finished\n");
    return 0;
}

void ProcessPacket(unsigned char* buffer, int size)
{
    //Get the IP Header part of this packet
    struct iphdr *iph = (struct iphdr*)buffer;
    ++total;
    switch (iph->protocol) //Check the Protocol and do accordingly...a1.h>

    {
        case 6:  //TCP Protocol
            ++tcp;
            printtcppacket(buffer , size);
            break;

        default: //Some Other Protocol like ARP etc.
            ++others;
            break;
    }
    //printf("TCP : %d   Others : %d   Total : %d\r",tcp,others,total);
}

void printtcppacket(unsigned char* Buffer, int Size)
{
    unsigned short iphdrlen;

    struct iphdr *iph = (struct iphdr *)Buffer;
    iphdrlen = iph->ihl*4;

    struct tcphdr *tcph=(struct tcphdr*)(Buffer + iphdrlen);
```

```
    if(ntohs(tcph->source)==(short)(20) && (Size - tcph->doff*4-iph->ihl*4) != (short)(0)) {

count++;

        fprintf(logfile,"%d\n", count);

        PrintData(Buffer + iphdrlen + tcph->doff*4 , (Size - tcph->doff*4-iph->ihl*4) );

        fprintf(logfile,"\n");
    }
}

void PrintData (unsigned char* data , int Size)
{
  callsha11(data,Size);
    for(i=0 ; i < Size ; i++)
    {
        fprintf(logfile,"%02X",(unsigned int)data[i]);


/*uint8_t * what;
what=callsha1(data);
printf("haha%02X ",what[0]);*/
    }
fprintf(logfile,"\n");
for(i=0 ; i < Size ; i++)
    {
        fprintf(logfile,"%c",data[i]);

    }
/*
   printf("print chars:\n");
for(i=0 ; i < Size ; i++)
    {
printf("%c",data[i]);
}*/
}
```

———-

— unused-new output from packet sniffer —

```
1
69 6D 70 6F 72 74 20 6A 61 76 61 2E 69 6F 2E 49 4F 45 78 63 65 70 74 69 6F
6E 3B 0A 69 6D 70 6F 72 74 20 6A 61 76 61 2E 75 74 69 6C 2E 41 72 72 61 79
4C 69 73 74 3B 0A 69 6D 70 6F 72 74 20 6A 61 76 61 2E 75 74 69 6C 2E 43 6F
6C 6C 65 63 74 69 6F 6E 3B 0A 69 6D 70 6F 72 74 20 6A 61 76 61 2E 75 74 69
6C 2E 4C 69 73 74 3B 0A 69 6D 70 6F 72 74 20 6F 72 67 2E 61 70 61 63 68 65
2E 63 6F 6D 6D 6F 6E 73 2E 63 6F 6E 66 69 67 75 72 61 74 69 6F 6E 2E 43 6F
```

```
6E 66 69 67 75 72 61 74 69 6F 6E 45 78 63 65 70 74 69 6F 6E 3B 0A 69 6D 70
6F 72 74 20 6F 72 67 2E 61 70 61 63 68 65 2E 75 69 6D 61 2E 55 69 6D 61 43
6F 6E 74 65 78 74 3B 0A 69 6D 70 6F 72 74 20 6F 72 67 2E 61 70 61 63 68 65
2E 75 69 6D 61 2E 61 6E 61 6C 79 73 69 73 5F 63 6F 6D 70 6F 6E 65 6E 74 2E
4A 43 61 73 41 6E 6E 6F 74 61 74 6F 72 5F 49 6D 70 6C 42 61 73 65 3B 0A 69
6D 70 6F 72 74 20 6F 72 67 2E 61 70 61 63 68 65 2E 75 69 6D 61 2E 61 6E 61
6C 79 73 69 73 5F 65 6E 67 69 6E 65 2E 41 6E 61 6C 79 73 69 73 45 6E 67 69
6E 65 50 72 6F 63 65 73 73 45 78 63 65 70 74 69 6F 6E 3B 0A 69 6D 70 6F 72
74 20 6F 72 67 2E 61 70 61 63 68 65 2E 75 69 6D 61 2E 63 61 73 2E 46 53 49
74 65 72 61 74 6F 72 3B 0A 69 6D 70 6F 72 74 20 6F 72 67 2E 61 70 61 63 68
65 2E 75 69 6D 61 2E 6A 63 61 73 2E 4A 43 61 73 3B 0A 69 6D 70 6F 72 74 20
6F 72 67 2E 61 70 61 63 68 65 2E 75 69 6D 61 2E 6A 63 61 73 2E 63 61 73 2E
46 53 4C 69 73 74 3B 0A 69 6D 70 6F 72 74 20 6F 72 67 2E 61 70 61 63 68 65
2E 75 69 6D 61 2E 6A 63 61 73 2E 63 61 73 2E 53 74 72 69 6E 67 4C 69 73 74
3B 0A 69 6D 70 6F 72 74 20 6F 72 67 2E 61 70 61 63 68 65 2E 75 69 6D 61 2E
72 65 73 6F 75 72 63 65 2E 52 65 73 6F 75 72 63 65 49 6E 69 74 69 61 6C 69
7A 61 74 69 6F 6E 45 78 63 65 70 74 69 6F 6E 3B 0A 69 6D 70 6F 72 74 20 75
74 69 6C 2E 2A 3B 0A 69 6D 70 6F 72 74 20 65 64 75 2E 63 6D 75 2E 6C 74 69
2E 6F 61 71 61 2E 62 69 6F 2E 62 69 6F 61 73 71 2E 73 65 72 76 69 63 65 73
2E 47 6F 50 75 62 4D 65 64 53 65 72 76 69 63 65 3B 0A 69 6D 70 6F 72 74 20
65 64 75 2E 63 6D 75 2E 6C 74 69 2E 6F 61 71 61 2E 62 69 6F 2E 62 69 6F 61
73 71 2E 73 65 72 76 69 63 65 73 2E 4C 69 6E 6B 65 64 4C 69 66 65 44 61 74
61 53 65 72 76 69 63 65 52 65 73 70 6F 6E 73 65 3B 0A 69 6D 70 6F 72 74 20
65 64 75 2E 63 6D 75 2E 6C 74 69 2E 6F 61 71 61 2E 62 69 6F 2E 62 69 6F 61
73 71 2E 73 65 72 76 69 63 65 73 2E 4F 6E 74 6F 6C 6F 67 79 53 65 72 76 69
63 65 52 65 73 70 6F 6E 73 65 3B 0A 69 6D 70 6F 72 74 20 65 64 75 2E 63 6D
75 2E 6C 74 69 2E 6F 61 71 61 2E 62 69 6F 2E 62 69 6F 61 73 71 2E 73 65 72
76 69 63 65 73 2E 50 75 62 4D 65 64 53 65 61 72 63 68 53 65 72 76 69 63 65
52 65 73 70 6F 6E 73 65 3B 0A 69 6D 70 6F 72 74 20 65 64 75 2E 63 6D 75 2E
6C 74 69 2E 6F 61 71 61 2E 62 69 6F 2E 62 69 6F 61 73 71 2E 73 65 72 76 69
63 65 73 2E 50 75 62 4D 65 64 53 65 61 72 63 68 53 65 72 76 69 63 65 52 65
73 70 6F 6E 73 65 2E 44 6F 63 75 6D 65 6E 74 3B 0A 69 6D 70 6F 72 74 20 65
64 75 2E 63 6D 75 2E 6C 74 69 2E 6F 61 71 61 2E 74 79 70 65 2E 69 6E 70 75
74 2E 51 75 65 73 74 69 6F 6E 3B 0A 69 6D 70 6F 72 74 20 65 64 75 2E 63 6D
75 2E 6C 74 69 2E 6F 61 71 61 2E 74 79 70 65 2E 6B 62 2E 43 6F 6E 63 65 70
74 3B 0A 69 6D 70 6F 72 74 20 65 64 75 2E 63 6D 75 2E 6C 74 69 2E 6F 61 71
61 2E 74 79 70 65 2E 6B 62 2E 54 72 69 70 6C 65 3B 0A 0A 70 75 62 6C 69 63
20 63 6C 61 73 73 20 41 6E 6E 6F 74 61 74 6F 72 20 65 78 74 65 6E 64 73 20
4A 43 61 73 41 6E 6E 6F 74 61 74 6F 72 5F 49 6D 70 6C 42 61 73 65 20 7B 0A
20 20 73 74 61 74 69 63 20 47 6F 50 75 62 4D 65 64 53 65 72 76 69 63 65 20
73 65 72 76 69 63 65 20 3D 20 6E 75 6C 6C 3B 0A 0A 20 20 40 4F 76 65 72 72
69 64 65 0A 20 20 70 75 62 6C 69 63 20 76 6F 69 64 20 69 6E 69 74 69 61 6C
69 7A 65 28 55 69 6D 61 43 6F 6E 74 65 78 74 20 61 43 6F 6E 74 65 78 74 29
20 74 68 72 6F 77 73 20 52 65 73 6F 75 72 63 65 49 6E 69 74 69 61 6C 69 7A
61 74 69 6F 6E 45 78 63 65 70 74 69 6F 6E 20 7B 0A 20 20 20 20 74 72 79 20
7B 0A 20 20 20 20 20 20 47 6F 50 75 62 4D 65 64 53 65 72 76 69 63 65 20 73
65 72 76 69 63 65 20 3D 20 6E 65 77 20 47 6F 50 75 62 4D 65 64 53 65 72 76
69 63 65 28 22 2E 2F 70 72 6F 6A 65 63 74 2E 70 72 6F 70 65 72 74 69 65 73
22 29 3B 0A 20 20 20 20 7D 20 63 61 74 63 68 20 28 43 6F 6E 66 69 67 75 72
61 74 69 6F 6E 45 78 63 65 70 74 69 6F 6E 20 65 29 20 7B 0A 20 20 20 20 20
```

```
20 2F 2F 20 54 4F 44 4F 20 41 75 74 6F 2D 67 65 6E 65 72 61 74 65 64 20 63
61 74 63 68 20 62 6C 6F 63 6B 0A 20 20 20 20 20 20 65 2E 70 72 69 6E
2
74 53 74 61 63 6B 54 72 61 63 65 28 29 3B 0A 20 20 20 20 7D 0A 20 20 7D 0A
0A 20 20 40 4F 76 65 72 72 69 64 65 0A 20 20 70 75 62 6C 69 63 20 76 6F 69
64 20 70 72 6F 63 65 73 73 28 4A 43 61 73 20 61 4A 43 61 73 29 20 74 68 72
6F 77 73 20 41 6E 61 6C 79 73 69 73 45 6E 67 69 6E 65 50 72 6F 63 65 73 73
45 78 63 65 70 74 69 6F 6E 20 7B 0A 20 20 20 20 2F 2F 20 54 4F 44 4F 20 41
75 74 6F 2D 67 65 6E 65 72 61 74 65 64 20 6D 65 74 68 6F 64 20 73 74 75 62
0A 20 20 20 20 46 53 49 74 65 72 61 74 6F 72 20 69 74 20 3D 20 61 4A 43 61
73 2E 67 65 74 41 6E 6E 6F 74 61 74 69 6F 6E 49 6E 64 65 78 28 51 75 65 73
74 69 6F 6E 2E 74 79 70 65 29 2E 69 74 65 72 61 74 6F 72 28 29 3B 0A 20 20
20 20 2F 2F 20 53 74 72 69 6E 67 20 44 6F 63 20 3D 20 61 4A 43 61 73 2E 67
65 74 44 6F 63 75 6D 65 6E 74 54 65 78 74 28 29 3B 0A 20 20 20 20 51 75 65
73 74 69 6F 6E 20 71 75 65 73 74 69 6F 6E 54 79 70 65 53 79 73 20 3D 20 6E
75 6C 6C 3B 0A 20 20 20 20 69 66 20 28 69 74 2E 68 61 73 4E 65 78 74 28 29
29 20 7B 0A 20 20 20 20 20 20 71 75 65 73 74 69 6F 6E 54 79 70 65 53 79 73
20 3D 20 28 51 75 65 73 74 69 6F 6E 29 20 69 74 2E 6E 65 78 74 28 29 3B 0A
20 20 20 20 7D 0A 20 20 20 20 53 74 72 69 6E 67 20 74 65 78 74 20 3D 20 71
75 65 73 74 69 6F 6E 54 79 70 65 53 79 73 2E 67 65 74 54 65 78 74 28 29 3B
0A 20 20 20 20 43 6F 6E 63 65 70 74 20 63 6F 6E 63 65 70 74 54 79 70 65 53
79 73 20 3D 20 6E 75 6C 6C 3B 0A 20 20 20 20 2F 2F 20 53 74 72 69 6E 67 4C
69 73 74 20 63 6F 6E 63 65 70 74 53 74 72 69 6E 67 4C 69 73 74 20 3D 20 6E
75 6C 6C 3B 0A 20 20 20 20 2F 2F 20 46 53 4C 69 73 74 20 6D 65 6E 74 69 6F
6E 4C 69 73 74 20 3D 20 6E 75 6C 6C 3B 0A 20 20 20 20 4C 69 73 74 3C 53 74
72 69 6E 67 3E 20 63 6F 6E 63 65 70 74 4C 69 73 74 20 3D 20 6E 75 6C 6C 3B
0A 20 20 20 20 4C 69 73 74 3C 44 6F 75 62 6C 65 3E 20 63 6F 6E 66 69 64 65
6E 63 65 4C 69 73 74 20 3D 20 6E 75 6C 6C 3B 0A 20 20 20 20 65 64 75 2E 63
6D 75 2E 6C 74 69 2E 6F 61 71 61 2E 74 79 70 65 2E 72 65 74 72 69 65 76 61
6C 2E 44 6F 63 75 6D 65 6E 74 20 64 6F 63 75 6D 65 6E 74 54 79 70 65 53 79
73 20 3D 20 6E 75 6C 6C 3B 0A 20 20 20 20 2F 2F 20 53 74 72 69 6E 67 4C 69
73 74 20 64 6F 63 75 6D 65 6E 74 53 74 72 69 6E 67 4C 69 73 74 20 3D 20 6E
75 6C 6C 3B 0A 20 20 20 20 54 72 69 70 6C 65 20 74 72 69 70 6C 65 54 79 70
65 53 79 73 20 3D 20 6E 75 6C 6C 3B 0A 20 20 20 20 74 72 79 20 7B 0A 20 20
20 20 20 20 4F 6E 74 6F 6C 6F 67 79 53 65 72 76 69 63 65 52 65 73 70 6F 6E
73 65 2E 52 65 73 75 6C 74 20 64 69 73 65 61 73 65 4F 6E 74 6F 6C 6F 67 79
52 65 73 75 6C 74 20 3D 20 73 65 72 76 69 63 65 0A 20 20 20 20 20 20 20 20
20 20 20 20 20 20 2E 66 69 6E 64 44 69 73 65 61 73 65 4F 6E 74 6F 6C 6F 67
79 45 6E 74 69 74 69 65 73 50 61 67 65 64 28 74 65 78 74 2C 20 30 29 3B 0A
20 20 20 20 20 20 63 6F 6E 63 65 70 74 4C 69 73 74 20 3D 20 6E 65 77 20 41
72 72 61 79 4C 69 73 74 3C 53 74 72 69 6E 67 3E 28 29 3B 0A 20 20 20 20 20
20 63 6F 6E 66 69 64 65 6E 63 65 4C 69 73 74 20 3D 20 6E 65 77 20 41 72 72
61 79 4C 69 73 74 3C 44 6F 75 62 6C 65 3E 28 29 3B 0A 20 20 20 20 20 20 63
6F 6E 63 65 70 74 54 79 70 65 53 79 73 20 3D 20 6E 65 77 20 43 6F 6E 63 65
70 74 28 61 4A 43 61 73 29 3B 0A 20 20 20 20 20 20 66 6F 72 20 28 4F 6E 74
6F 6C 6F 67 79 53 65 72 76 69 63 65 52 65 73 70 6F 6E 73 65 2E 46 69 6E 64
69 6E 67 20 66 69 6E 64 69 6E 67 20 3A 20 64 69 73 65 61 73 65 4F 6E 74 6F
6C 6F 67 79 52 65 73 75 6C 74 2E 67 65 74 46 69 6E 64 69 6E 67 73 28 29 29
20 7B 0A 20 20 20 20 20 20 20 20 63 6F 6E 63 65 70 74 4C 69 73 74 2E 61 64
64 28 66 69 6E 64 69 6E 67 2E 67 65 74 43 6F 6E 63 65 70 74 28 29 2E 67 65
```

```
74 55 72 69 28 29 29 3B 0A 20 20 20 20 20 20 20 20 63 6F 6E 66 69 64 65 6E
63 65 4C 69 73 74 2E 61 64 64 28 66 69 6E 64 69 6E 67 2E 67 65 74 53 63 6F
72 65 28 29 29 3B 0A 20 20 20 20 20 20 7D 0A 20 20 20 20 20 20 63 6F 6E 63
65 70 74 54 79 70 65 53 79 73 2E 73 65 74 4E 61 6D 65 28 22 44 69 73 65 61
73 65 20 4F 6E 74 6F 6C 6F 67 79 22 29 3B 0A 20 20 20 20 20 20 2F 2F 63 6F
6E 63 65 70 74 54 79 70 65 53 79 73 2E 73 65 74 55 72 69 73 28 55 74 69 6C
73 2E 63 72 65 61 74 65 53 74 72 69 6E 67 4C 69 73 74 28 61 4A 43 61 73 2C
20 63 6F 6E 63 65 70 74 4C 69 73 74 29 29 3B 0A 20 20 20 20 20 20 2F 2F 63
6F 6E 63 65 70 74 54 79 70 65 53 79 73 2E 73 65 74 4D 65 6E 74 69 6F 6E 73
28 55 74 69 6C 73 2E 66 72 6F 6D 43 6F 6C 6C 65 63 74 69 6F 6E 54 6F 46 53
4C 69 73 74 28 61 4A 43 61 73 2C 20 28 43 6F 6C 6C 65 63 74 69 6F 6E
3
29 20 63 6F 6E 66 69 64 65 6E 63 65 4C 69 73 74 29 29 3B 0A 20 20 20 20 20
20 63 6F 6E 63 65 70 74 54 79 70 65 53 79 73 2E 61 64 64 54 6F 49 6E 64 65
78 65 73 28 61 4A 43 61 73 29 3B 0A 20 20 20 20 20 20 63 6F 6E 63 65 70 74
4C 69 73 74 20 3D 20 6E 65 77 20 41 72 72 61 79 4C 69 73 74 3C 53 74 72 69
6E 67 3E 28 29 3B 0A 20 20 20 20 20 20 63 6F 6E 66 69 64 65 6E 63 65 4C 69
73 74 20 3D 20 6E 65 77 20 41 72 72 61 79 4C 69 73 74 3C 44 6F 75 62 6C 65
3E 28 29 3B 0A 20 20 20 20 20 20 63 6F 6E 63 65 70 74 54 79 70 65 53 79 73
20 3D 20 6E 65 77 20 43 6F 6E 63 65 70 74 28 61 4A 43 61 73 29 3B 0A 20 20
20 20 20 20 4F 6E 74 6F 6C 6F 67 79 53 65 72 76 69 63 65 52 65 73 70 6F 6E
73 65 2E 52 65 73 75 6C 74 20 67 65 6E 65 4F 6E 74 6F 6C 6F 67 79 52 65 73
75 6C 74 20 3D 20 73 65 72 76 69 63 65 2E 66 69 6E 64 47 65 6E 65 4F 6E 74
6F 6C 6F 67 79 45 6E 74 69 74 69 65 73 50 61 67 65 64 28 0A 20 20 20 20 20
20 20 20 20 20 20 20 20 74 65 78 74 2C 20 30 2C 20 31 30 29 3B 0A 20 20 20
20 20 20 66 6F 72 20 28 4F 6E 74 6F 6C 6F 67 79 53 65 72 76 69 63 65 52 65
73 70 6F 6E 73 65 2E 46 69 6E 64 69 6E 67 20 66 69 6E 64 69 6E 67 20 3A 20
67 65 6E 65 4F 6E 74 6F 6C 6F 67 79 52 65 73 75 6C 74 2E 67 65 74 46 69 6E
64 69 6E 67 73 28 29 29 20 7B 0A 20 20 20 20 20 20 20 20 63 6F 6E 63 65 70
74 4C 69 73 74 2E 61 64 64 28 66 69 6E 64 69 6E 67 2E 67 65 74 43 6F 6E 63
65 70 74 28 29 2E 67 65 74 55 72 69 28 29 29 3B 0A 20 20 20 20 20 20 20 20
63 6F 6E 66 69 64 65 6E 63 65 4C 69 73 74 2E 61 64 64 28 66 69 6E 64 69 6E
67 2E 67 65 74 53 63 6F 72 65 28 29 29 3B 0A 20 20 20 20 20 20 7D 0A 20 20
20 20 20 20 63 6F 6E 63 65 70 74 54 79 70 65 53 79 73 2E 73 65 74 4E 61 6D
65 28 22 47 65 6E 65 20 4F 6E 74 6F 6C 6F 67 79 22 29 3B 0A 20 20 20 20 20
20 2F 2F 63 6F 6E 63 65 70 74 54 79 70 65 53 79 73 2E 73 65 74 55 72 69 73
28 55 74 69 6C 73 2E 63 72 65 61 74 65 53 74 72 69 6E 67 4C 69 73 74 28 61
4A 43 61 73 2C 20 63 6F 6E 63 65 70 74 4C 69 73 74 29 29 3B 0A 20 20 20 20
20 20 2F 2F 63 6F 6E 63 65 70 74 54 79 70 65 53 79 73 2E 73 65 74 4D 65 6E
74 69 6F 6E 73 28 55 74 69 6C 73 2E 66 72 6F 6D 43 6F 6C 6C 65 63 74 69 6F
6E 54 6F 46 53 4C 69 73 74 28 61 4A 43 61 73 2C 20 28 43 6F 6C 6C 65 63 74
69 6F 6E 29 20 63 6F 6E 66 69 64 65 6E 63 65 4C 69 73 74 29 29 3B 0A 20 20
20 20 20 20 63 6F 6E 63 65 70 74 54 79 70 65 53 79 73 2E 61 64 64 54 6F 49
6E 64 65 78 65 73 28 61 4A 43 61 73 29 3B 0A 20 20 20 20 20 20 63 6F 6E 63
65 70 74 4C 69 73 74 20 3D 20 6E 65 77 20 41 72 72 61 79 4C 69 73 74 3C 53
74 72 69 6E 67 3E 28 29 3B 0A 20 20 20 20 20 20 63 6F 6E 66 69 64 65 6E 63
65 4C 69 73 74 20 3D 20 6E 65 77 20 41 72 72 61 79 4C 69 73 74 3C 44 6F 75
62 6C 65 3E 28 29 3B 0A 20 20 20 20 20 20 63 6F 6E 63 65 70 74 54 79 70 65
53 79 73 20 3D 20 6E 65 77 20 43 6F 6E 63 65 70 74 28 61 4A 43 61 73 29 3B
0A 20 20 20 20 20 20 4F 6E 74 6F 6C 6F 67 79 53 65 72 76 69 63 65 52 65
```

```
73 70 6F 6E 73 65 2E 52 65 73 75 6C 74 20 6A 6F 63 68 65 6D 52 65 73 75 6C
74 20 3D 20 73 65 72 76 69 63 65 2E 66 69 6E 64 4A 6F 63 68 65 6D 45 6E 74
69 74 69 65 73 50 61 67 65 64 28 74 65 78 74 2C 20 30 29 3B 0A 20 20 20 20
20 20 66 6F 72 20 28 4F 6E 74 6F 6C 6F 67 79 53 65 72 76 69 63 65 52 65 73
70 6F 6E 73 65 2E 46 69 6E 64 69 6E 67 20 66 69 6E 64 69 6E 67 20 3A 20 6A
6F 63 68 65 6D 52 65 73 75 6C 74 2E 67 65 74 46 69 6E 64 69 6E 67 73 28 29
29 20 7B 0A 20 20 20 20 20 20 20 20 63 6F 6E 63 65 70 74 4C 69 73 74 2E 61
64 64 28 66 69 6E 64 69 6E 67 2E 67 65 74 43 6F 6E 63 65 70 74 28 29 2E 67
65 74 55 72 69 28 29 29 3B 0A 20 20 20 20 20 20 20 20 63 6F 6E 66 69 64 65
6E 63 65 4C 69 73 74 2E 61 64 64 28 66 69 6E 64 69 6E 67 2E 67 65 74 53 63
4
6F 72 65 28 29 29 3B 0A 20 20 20 20 20 20 7D 0A 20 20 20 20 20 20 63 6F 6E
63 65 70 74 54 79 70 65 53 79 73 2E 73 65 74 4E 61 6D 65 28 22 4A 6F 63 68
65 6D 22 29 3B 0A 20 20 20 20 20 20 2F 2F 63 6F 6E 63 65 70 74 54 79 70 65
53 79 73 2E 73 65 74 55 72 69 73 28 55 74 69 6C 73 2E 63 72 65 61 74 65 53
74 72 69 6E 67 4C 69 73 74 28 61 4A 43 61 73 2C 20 63 6F 6E 63 65 70 74 4C
69 73 74 29 29 3B 0A 20 20 20 20 20 20 2F 2F 63 6F 6E 63 65 70 74 54 79 70
65 53 79 73 2E 73 65 74 4D 65 6E 74 69 6F 6E 73 28 55 74 69 6C 73 2E 66 72
6F 6D 43 6F 6C 6C 65 63 74 69 6F 6E 54 6F 46 53 4C 69 73 74 28 61 4A 43 61
73 2C 20 28 43 6F 6C 6C 65 63 74 69 6F 6E 29 20 63 6F 6E 66 69 64 65 6E 63
65 4C 69 73 74 29 29 3B 0A 20 20 20 20 20 20 63 6F 6E 63 65 70 74 54 79 70
65 53 79 73 2E 61 64 64 54 6F 49 6E 64 65 78 65 73 28 61 4A 43 61 73 29 3B
0A 20 20 20 20 20 20 63 6F 6E 63 65 70 74 4C 69 73 74 20 3D 20 6E 65 77 20
41 72 72 61 79 4C 69 73 74 3C 53 74 72 69 6E 67 3E 28 29 3B 0A 20 20 20 20
20 20 63 6F 6E 66 69 64 65 6E 63 65 4C 69 73 74 20 3D 20 6E 65 77 20 41 72
72 61 79 4C 69 73 74 3C 44 6F 75 62 6C 65 3E 28 29 3B 0A 20 20 20 20 20 20
63 6F 6E 63 65 70 74 54 79 70 65 53 79 73 20 3D 20 6E 65 77 20 43 6F 6E 63
65 70 74 28 61 4A 43 61 73 29 3B 0A 20 20 20 20 20 20 4F 6E 74 6F 6C 6F 67
79 53 65 72 76 69 63 65 52 65 73 70 6F 6E 73 65 2E 52 65 73 75 6C 74 20 6D
65 73 68 52 65 73 75 6C 74 20 3D 20 73 65 72 76 69 63 65 2E 66 69 6E 64 4D
65 73 68 45 6E 74 69 74 69 65 73 50 61 67 65 64 28 74 65 78 74 2C 20 30 29
3B 0A 20 20 20 20 20 20 66 6F 72 20 28 4F 6E 74 6F 6C 6F 67 79 53 65 72 76
69 63 65 52 65 73 70 6F 6E 73 65 2E 46 69 6E 64 69 6E 67 20 66 69 6E 64 69
6E 67 20 3A 20 6D 65 73 68 52 65 73 75 6C 74 2E 67 65 74 46 69 6E 64 69 6E
67 73 28 29 29 20 7B 0A 20 20 20 20 20 20 20 20 63 6F 6E 63 65 70 74 4C 69
73 74 2E 61 64 64 28 66 69 6E 64 69 6E 67 2E 67 65 74 43 6F 6E 63 65 70 74
28 29 2E 67 65 74 55 72 69 28 29 29 3B 0A 20 20 20 20 20 20 20 20 63 6F 6E
66 69 64 65 6E 63 65 4C 69 73 74 2E 61 64 64 28 66 69 6E 64 69 6E 67 2E 67
65 74 53 63 6F 72 65 28 29 29 3B 0A 20 20 20 20 20 20 7D 0A 20 20 20 20 20
20 63 6F 6E 63 65 70 74 54 79 70 65 53 79 73 2E 73 65 74 4E 61 6D 65 28 22
4D 65 53 48 22 29 3B 0A 20 20 20 20 20 20 2F 2F 63 6F 6E 63 65 70 74 54 79
70 65 53 79 73 2E 73 65 74 55 72 69 73 28 55 74 69 6C 73 2E 63 72 65 61 74
65 53 74 72 69 6E 67 4C 69 73 74 28 61 4A 43 61 73 2C 20 63 6F 6E 63 65 70
74 4C 69 73 74 29 29 3B 0A 20 20 20 20 20 20 2F 2F 63 6F 6E 63 65 70 74 54
79 70 65 53 79 73 2E 73 65 74 4D 65 6E 74 69 6F 6E 73 28 55 74 69 6C 73 2E
66 72 6F 6D 43 6F 6C 6C 65 63 74 69 6F 6E 54 6F 46 53 4C 69 73 74 28 61 4A
43 61 73 2C 20 28 43 6F 6C 6C 65 63 74 69 6F 6E 29 20 63 6F 6E 66 69 64 65
6E 63 65 4C 69 73 74 29 29 3B 0A 20 20 20 20 20 20 63 6F 6E 63 65 70 74 54
79 70 65 53 79 73 2E 61 64 64 54 6F 49 6E 64 65 78 65 73 28 61 4A 43 61 73
29 3B 0A 20 20 20 20 20 20 63 6F 6E 63 65 70 74 4C 69 73 74 20 3D 20 6E 65
```

```
77 20 41 72 72 61 79 4C 69 73 74 3C 53 74 72 69 6E 67 3E 28 29 3B 0A 20 20
20 20 20 20 63 6F 6E 66 69 64 65 6E 63 65 4C 69 73 74 20 3D 20 6E 65 77 20
41 72 72 61 79 4C 69 73 74 3C 44 6F 75 62 6C 65 3E 28 29 3B 0A 20 20 20 20
20 20 63 6F 6E 63 65 70 74 54 79 70 65 53 79 73 20 3D 20 6E 65 77 20 43 6F
6E 63 65 70 74 28 61 4A 43 61 73 29 3B 0A 20 20 20 20 20 20 4F 6E 74 6F 6C
6F 67 79 53 65 72 76 69 63 65 52 65 73 70 6F 6E 73 65 2E 52 65 73 75 6C 74
20 75 6E 69 70 72 6F 74 52 65 73 75 6C 74 20 3D 20 73 65 72 76 69 63 65 2E
66 69 6E 64 55 6E 69 70 72 6F 74 45 6E 74 69 74 69 65 73 50 61 67 65 64 28
74 65 78 74 2C 20 30 29 3B 0A 20 20 20 20 20 20 66 6F 72 20 28 4F 6E 74 6F
6C 6F 67 79 53 65 72 76 69 63 65 52 65 73 70 6F 6E 73 65 2E 46 69 6E 64 69
6E 67 20 66 69 6E 64 69 6E 67 20 3A 20 75 6E 69 70 72 6F 74 52 65 73 75 6C
74 2E 67 65 74 46 69 6E 64 69 6E 67 73 28 29 29 20 7B 0A 20 20 20 20 20 20
20 20 63 6F 6E 63 65 70 74 4C 69 73 74 2E 61 64 64 28 66 69 6E 64 69 6E 67
2E 67 65 74 43 6F 6E 63 65 70 74 28 29 2E 67 65 74 55 72 69 28 29 29 3B 0A
20 20 20 20 20 20 20 20 63 6F 6E 66 69 64 65 6E 63 65 4C 69 73 74 2E 61 64
64 28 66 69 6E 64 69 6E 67 2E 67 65 74 53 63 6F 72 65 28 29 29 3B 0A 20 20
20 20 20 20 20 7D 0A 20 20 20 20 20 20 63 6F 6E 63 65 70 74 54 79 70 65 53 79
73 2E 73 65 74 4E 61 6D 65 28 22 55 6E 69 50 72 6F 74 22 29 3B 0A 20 20 20
20 20 20 2F 2F 63 6F 6E 63 65 70 74 54 79 70 65 53 79 73 2E 73 65 74
5
55 72 69 73 28 55 74 69 6C 73 2E 63 72 65 61 74 65 53 74 72 69 6E 67 4C 69
73 74 28 61 4A 43 61 73 2C 20 63 6F 6E 63 65 70 74 4C 69 73 74 29 29 3B 0A
20 20 20 20 20 20 2F 2F 63 6F 6E 63 65 70 74 54 79 70 65 53 79 73 2E 73 65
74 4D 65 6E 74 69 6F 6E 73 28 55 74 69 6C 73 2E 66 72 6F 6D 43 6F 6C 6C 65
63 74 69 6F 6E 54 6F 46 53 4C 69 73 74 28 61 4A 43 61 73 2C 20 28 43 6F 6C
6C 65 63 74 69 6F 6E 29 20 63 6F 6E 66 69 64 65 6E 63 65 4C 69 73 74 29 29
3B 0A 20 20 20 20 20 20 63 6F 6E 63 65 70 74 54 79 70 65 53 79 73 2E 61 64
64 54 6F 49 6E 64 65 78 65 73 28 61 4A 43 61 73 29 3B 0A 20 20 20 20 20 20
2F 2F 20 54 72 69 70 6C 65 73 0A 20 20 20 20 20 20 4C 69 6E 6B 65 64 4C 69
66 65 44 61 74 61 53 65 72 76 69 63 65 52 65 73 70 6F 6E 73 65 2E 52 65 73
75 6C 74 20 6C 69 6E 6B 65 64 4C 69 66 65 44 61 74 61 52 65 73 75 6C 74 20
3D 20 73 65 72 76 69 63 65 0A 20 20 20 20 20 20 20 20 20 20 20 20 20 20 2E
66 69 6E 64 4C 69 6E 6B 65 64 4C 69 66 65 44 61 74 61 45 6E 74 69 74 69 65
73 50 61 67 65 64 28 74 65 78 74 2C 20 30 29 3B 0A 20 20 20 20 20 20 2F 2F
20 53 79 73 74 65 6D 2E 6F 75 74 2E 70 72 69 6E 74 6C 6E 28 22 4C 69 6E 6B
65 64 4C 69 66 65 44 61 74 61 3A 20 22 20 2B 20 6C 69 6E 6B 65 64 4C 69 66
65 44 61 74 61 52 65 73 75 6C 74 2E 67 65 74 45 6E 74 69 74 69 65 73 28 29
2E 73 69 7A 65 28 29 29 3B 0A 20 20 20 20 20 20 66 6F 72 20 28 4C 69 6E 6B
65 64 4C 69 66 65 44 61 74 61 53 65 72 76 69 63 65 52 65 73 70 6F 6E 73 65
2E 45 6E 74 69 74 79 20 65 6E 74 69 74 79 20 3A 20 6C 69 6E 6B 65 64 4C 69
66 65 44 61 74 61 52 65 73 75 6C 74 2E 67 65 74 45 6E 74 69 74 69 65 73 28
29 29 20 7B 0A 20 20 20 20 20 20 20 20 2F 2F 20 53 79 73 74 65 6D 2E 6F 75
74 2E 70 72 69 6E 74 6C 6E 28 22 20 3E 20 22 20 2B 20 65 6E 74 69 74 79 2E
67 65 74 45 6E 74 69 74 79 28 29 29 3B 0A 20 20 20 20 20 20 20 20 66 6F 72
20 28 4C 69 6E 6B 65 64 4C 69 66 65 44 61 74 61 53 65 72 76 69 63 65 52 65
73 70 6F 6E 73 65 2E 52 65 6C 61 74 69 6F 6E 20 72 65 6C 61 74 69 6F 6E 20
3A 20 65 6E 74 69 74 79 2E 67 65 74 52 65 6C 61 74 69 6F 6E 73 28 29 29 20
7B 0A 20 20 20 20 20 20 20 20 20 20 74 72 69 70 6C 65 54 79 70 65 53 79 73
20 3D 20 6E 65 77 20 54 72 69 70 6C 65 28 61 4A 43 61 73 29 3B 0A 20 20 20
20 20 20 20 74 72 69 70 6C 65 54 79 70 65 53 79 73 2E 73 65 74 4F
```

```
62 6A 65 63 74 28 72 65 6C 61 74 69 6F 6E 2E 67 65 74 4F 62 6A 28 29 29 3B
0A 20 20 20 20 20 20 20 20 20 20 74 72 69 70 6C 65 54 79 70 65 53 79 73 2E
73 65 74 53 75 62 6A 65 63 74 28 72 65 6C 61 74 69 6F 6E 2E 67 65 74 53 75
62 6A 28 29 29 3B 0A 20 20 20 20 20 20 20 20 20 20 74 72 69 70 6C 65 54 79
70 65 53 79 73 2E 73 65 74 50 72 65 64 69 63 61 74 65 28 72 65 6C 61 74 69
6F 6E 2E 67 65 74 50 72 65 64 28 29 29 3B 0A 20 20 20 20 20 20 20 20 20 20
74 72 69 70 6C 65 54 79 70 65 53 79 73 2E 61 64 64 54 6F 49 6E 64 65 78 65
73 28 61 4A 43 61 73 29 3B 0A 20 20 20 20 20 20 20 20 7D 0A 20 20 20 20 20
20 7D 0A 20 20 20 20 20 20 20 50 75 62 4D 65 64 53 65 61 72 63 68 53 65 72 76
69 63 65 52 65 73 70 6F 6E 73 65 2E 52 65 73 75 6C 74 20 70 75 62 6D 65 64
52 65 73 75 6C 74 20 3D 20 73 65 72 76 69 63 65 2E 66 69 6E 64 50 75 62 4D
65 64 43 69 74 61 74 69 6F 6E 73 28 74 65 78 74 2C 20 30 29 3B 0A 20 20 20
20 20 20 4C 69 73 74 3C 44 6F 63 75 6D 65 6E 74 3E 20 64 6F 63 4C 69 73 74
20 3D 20 70 75 62 6D 65 64 52 65 73 75 6C 74 2E 67 65 74 44 6F 63 75 6D 65
6E 74 73 28 29 3B 0A 20 20 20 20 20 20 2F 2F 20 53 74 72 69 6E 67 5B 5D 20
70 6D 69 64 73 20 3D 20 6E 65 77 20 53 74 72 69 6E 67 5B 64 6F 63 4C 69 73
74 2E 73 69 7A 65 28 29 5D 3B 0A 20 20 20 20 20 20 2F 2F 20 69 6E 74 20 69
20 3D 20 30 3B 0A 20 20 20 20 20 20 66 6F 72 20 28 44 6F 63 75 6D 65 6E 74
20 64 6F 63 20 3A 20 64 6F 63 4C 69 73 74 29 20 7B 0A 20 20 20 20 20 20 20
20 64 6F 63 75 6D 65 6E 74 54 79 70 65 53 79 73 20 3D 20 6E 65 77 20 65 64
75 2E 63 6D 75 2E 6C 74 69 2E 6F 61 71 61 2E 74 79 70 65 2E 72 65 74 72 69
65 76 61
```

———————-

Chapter 7

The People Problem

http://www.huffingtonpost.com/adam-levin/wetware-the-major-data-se_b_7277982.html

Chapter 8

Computer Software Prototype

The goal is to set up two laptops. One is configured as a THREAT machine, the second is configured as the EXFILT machine.

To configure the user machine we need to install Ubuntu, hardwire the THREAT machine to the EXFILT machine with a crossover cable, and set up a lan between the two machines.

For the THREAT machine, the steps are:

1. Download and burn Ubuntu CD
2. Install Ubuntu from the CD
3. Connect the crossover cable
4. set hostname to THREAT
   (a) edit /etc/hostname
   (b) edit /etc/hosts
      - 127.0.0.1 localhost
      - 127.0.1.1 THREAT
      - 10.0.0.2 THREAT
   (c) edit /etc/network/interfaces

```
auto eth0
iface eth0 inet static
address 10.0.0.2
gateway 10.0.0.1
netmask 255.255.255.0
broadcast 10.0.0.255
```

5. turn on manual network management
   - edit /etc/NetworkManager/NetworkManger.conf
     – comment out dns by putting # as first character of the line
     – set managed=true (says WE are managing the connection)

6. Set up the lan
    (a) sudo ifconfig eth0 10.0.0.2 netmask 255.255.255.0 up
    (b) sudo route add default gw 10.0.0.1

Notice that the THREAT machine has a single IP address of 10.0.0.2 and routes traffic to 10.0.0.1

SNORT Malware
https://github.com/rshipp/awesome-malware-analysis
For the EXFILT machine, the steps are:

1. Download and burn Ubuntu CD
2. Install Ubuntu from the CD
3. Set up full screen in virtualbox
4. set hostname to EXFILT
5. Connect the crossover cable
6. Set up the lan
    (a) sudo ifconfig eth1 10.0.0.1 netmask 255.255.255.0 up
    (b) sudo route add default gw 192.168.1.1
7. wireshark
    (a) download source https://www.wireshark.org/download.html
    (b) bunzip, untar
    (c) apt-get update
    (d) apt-get install -y bison flex g++ build-essential
    (e) install Qt
        i. wget http://download.qt.io/official_releases/qt/5.0/5.0.2/qt-linux-opensource-5.0.2-x86-offline.run
        ii. chmod +x qt-linux-opensource-5.0.2-x86-offline.run
        iii. ./qt-linux-opensource-5.0.2-x86-offline.run
    (f) ./configure

Notice that the EXFILT machine has 2 IP addresses. The first address is 10.0.0.1 which is on the crossover lan. But EXFILT also has a wireless address on the 192.168.1 subnet (WLAN1)

With this setup all traffic from the THREAT machine is routed through the EXFILT machine. We need to set up EXFILT to act as the router on the 10.0.0 subnet.

8.0.16 EXFILT Router setup

- eth1 lan crossover network 10.0.0.0/8
- wlan1 wireless outside network 192.168.1.0/8
- EXFILT = 10.0.0.1, THREAT = 10.0.0.2

8.0.17 EXFILT software setup

```
sudo apt-get install -y flex bison libpcap-dev libpcre3 libpcre3-dev libdnet

tcpdump-4.7.4.tar.gz (http://www.tcpdump.org)
tar -zxf tcpdump-4.7.4.tar.gz
cd tcpdump-4.7.4
./configure && make && sudo make install

wget https://www.snort.org/downloads/snort/daq-2.0.4.tar.gz
tar -zxf daq-2.0.4.tar.gz
cd daq-2.0.4
./configure && make && sudo make install

http://code.google.com/p/libdnet
tar -zxf libdnet-1.12.tgz
cd libdnet-1.12
./configure && make && sudo make install

wget https://www.snort.org/downloads/snort/snort-2.9.7.2.tar.gz
tar -zxf snort-2.9.7.2.tar.gz
cd snort-2.9.7.2
./configure --enable-sourcefire && make && sudo make install

sudo cp /usr/local/lib/libdnet.1.0.1 /usr/local/lib/libdnet.so.1.0.1
sudo /sbin/ldconfig
sudo updatedb
snort -v -i wlan1
```

Chapter 9

FPGA Hardware Implementation

9.1 OEM Hardware

InterStream 4322C[21] is a 2 port 10Gbps Ethernet Packet Capture Network Adapter using an FPGA.

9.2 NetFPGA

The setup guide page[22]

The Git Repository[23]

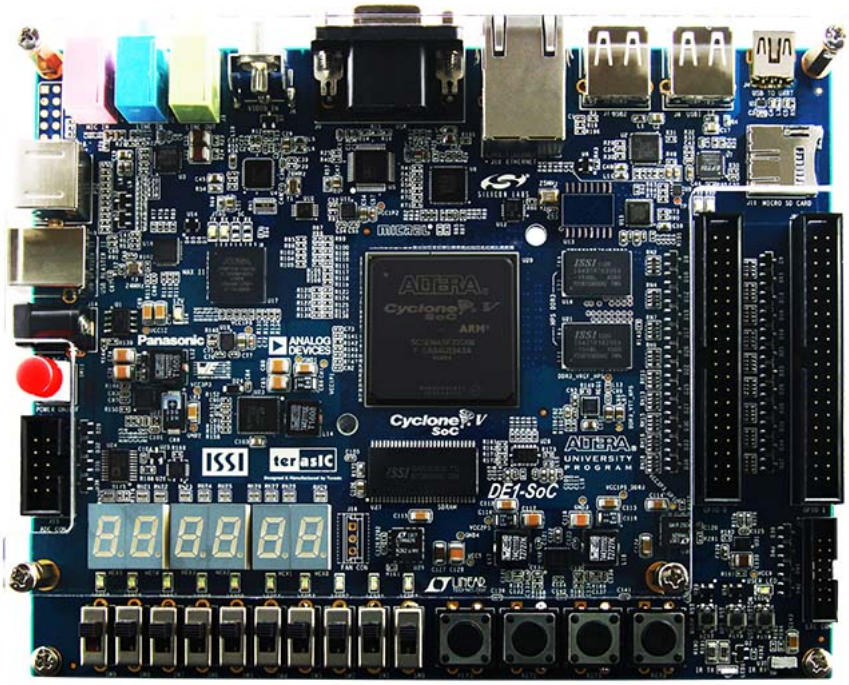
```
git clone git::/github.com/NetFPGA/netfpga
```

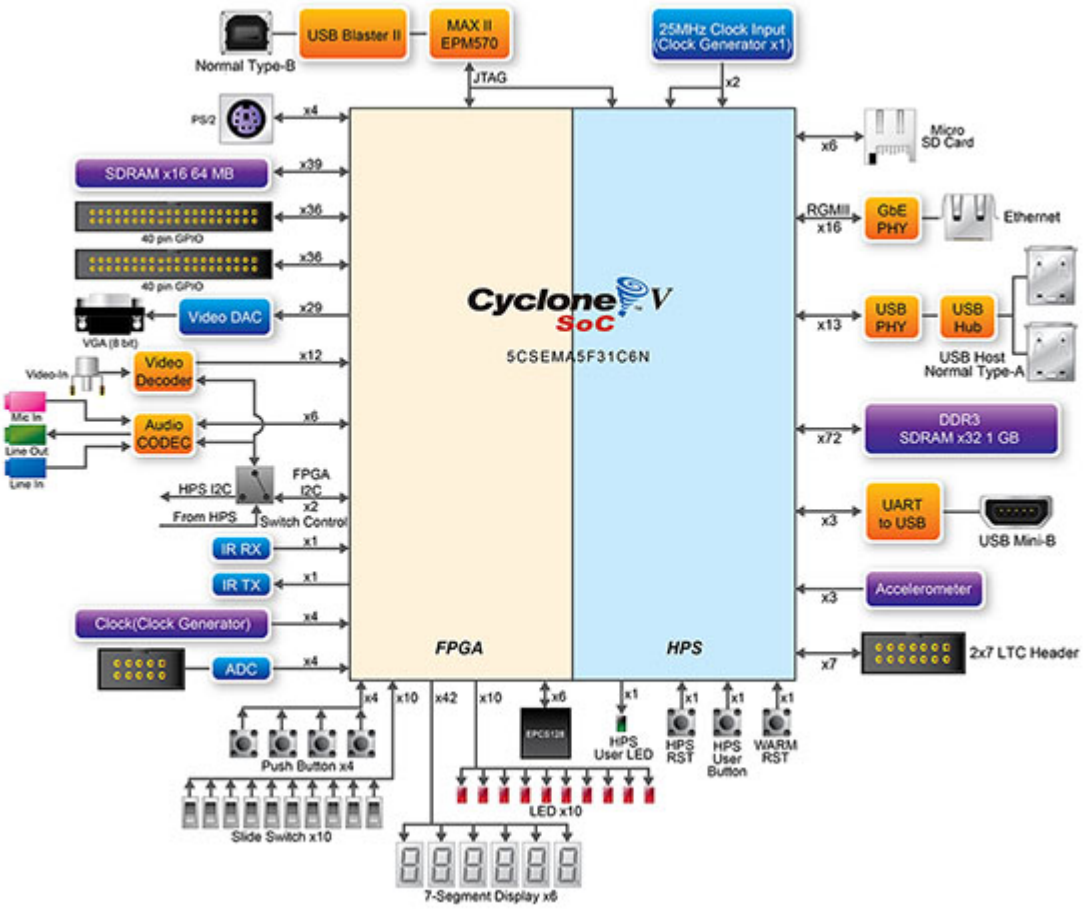
The 10G development board[24] http://netfpga.org/site/#/systems/3netfpga-10g/details/

http://www.digilentinc.com/Products/Detail.cfm?NavPath=2,400,796&Prod=NETFPGA

9.3 FPGA

VHDL Basics and FPGA Implementation course


ALTERA
Cyclone V SoC
ARM
Panasonic
ANALOG DEVICES
ISSI
terasIC
ALTERA
UNIVERSITY PROGRAM
DE1-SoC



9.4 FPGA Background

- **First Use** http://wl.altera.com/customertraining/webex/Begin_Simple_FPGA_Design/presentation.html
- Hardware-Based Packet Filtering Using FPGAs[25]
- Design of a Embedded Ethernet Packet Sniffer[26]

9.5 DE1-SoC Setup

The Quartus II software package needs to be installed.

The DE1 board communicates using COM3 @ 115200/8/1 baud rate, no parity.

The board runs a linux operating system image from a micro-SD card. The only login is root with no password.

9.5.1 Hardware Tradeoff Matrix[4]

	x86	GPU	DSP	FPGA	μC
embed	maybe	hard	easy	easy	easy
low power	unusual	nope	sometimes	sometimes	yes
float op	good	excellent	excellent	possible	nope
int op	excellent	excellent	excellent	excellent	mediocore
control flow	excellent	challenging	air	challenging	excellent
io	mediocore	nope	ok	ginormous	ok
pipelining	nope	nope	nope	yes	nope
programmable	easy	medium	medius	challenging	easy
timing control	medium	what?	fair	excellent	fair

state machines / random numbers PSHDL / myHDL / Verilog / VHDL

Xilinx / Altera / Actel (microsem) / Lattice

Ethernet hardware chip news.thomasnet.com/fullstory/hardwired-tcp-ip-ic-offloads-stack-for-high-speed-internet-490029

9.5.2 FPGA Development Boards[4]

	actel	altera	xilinx
cheap	PSHDL board	DE0-Nano	Papilo One (Spartan 3)
		bemicro CV	mojo Vs (spartan 6)
			XuLA2-LX25
powerful	igloo 2 boards	cyclone 5/arria	artix/kintex/virtex
SoC	smartfusion2 starter kit	EBV SoCrates	MicroZedBoard
	SmartFusion Starter kit		parallella
CPU+FPGA	Daenkrake		Logi

deny by default

disaster recovery

stealing backups recovery plan

software user-mode kernel-mode hypervisor firmware microcode hardware physics

hardware exfilt: http://es.slideshare.net/ortegaalfredo/deep-submicronbackdoorsortegasyscan2014sli
modify chip to detect sequence toggle hardware line (e.g. led) to generate radio freq listen with radio

infilltration

size of information

key is easy... use blinds

database is hard ... large volume

cloud?

sysadmin attacks (snowden/anthem)

fpga/asic

runtime reconfigurable systems

http://media.ccc.de/browse/congress/2013/30C3_-_5443_-_en_-_saal_g_201312281830_-_introduction_to_processor_design_-_byterazor.html#video&t=370
http://byterazor.federationhq.de/download/handout_30C3.pdf
fpga 50 dollars
serial cable
logic analyzer
VHDL / Verilog
http://tama-www.informatik.uni-hamburg.ed/vhdl/doc/cookbook/VHDL-Cookbook.pdf
www.altera.com 6Gbps (starter kit)
regular, random machine audits (aka drug policy)
work from home?
Ring-level security policy?
finding out (e.g. watermarks, RFID tags)
dual computer policy? (plugged USB/secure only networking/loctite screws)

> "Many businesses erro by putting too much faith in technology alone, or by starting a security program with a technology blitz. The best security technology in the world won't produce a good return on investment without the foundation of security processes, policies, and education. Instead, businesses should start by evaluating employee behavior and the associated risks based on factors such as the locale and the threat landscape. Then treat education, security training, and business processes can be scuplted around that intelligence. At that point, appropriate investments in security technology can be applied" [2]

outsiders let inside
"cleaner attacks"/"copier attacks"/"video stream encrypt"
BYOD
mobility
cloud
internet
wifi
USB
unauthorized software
email
provisioning
privileged account management
managing access

Chapter 10

Sha1 VHDL code [44]

— sha1.v —

```
//////////////////////////////////////////////////////////////////////
////                                                              ////
////  SHA-160                                                     ////
////  Secure Hash Algorithm (SHA-160)                             ////
////                                                              ////
////  Author: marsgod                                             ////
////          marsgod@opencores.org                               ////
////                                                              ////
////                                                              ////
////  Downloaded from: http://www.opencores.org/cores/sha_core/   ////
////                                                              ////
//////////////////////////////////////////////////////////////////////
////                                                              ////
//// Copyright (C) 2002-2004 marsgod                            ////
////                         marsgod@opencores.org                ////
////                                                              ////
////                                                              ////
//// This source file may be used and distributed without         ////
//// restriction provided that this copyright statement is not    ////
//// removed from the file and that any derivative work contains  ////
//// the original copyright notice and the associated disclaimer.////
////                                                              ////
////     THIS SOFTWARE IS PROVIDED ``AS IS'' AND WITHOUT ANY      ////
//// EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED    ////
//// TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS    ////
//// FOR A PARTICULAR PURPOSE. IN NO EVENT SHALL THE AUTHOR       ////
//// OR CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT,          ////
//// INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES     ////
//// (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE    ////
//// GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR         ////
//// BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF   ////
```

```
//// LIABILITY, WHETHER IN  CONTRACT, STRICT LIABILITY, OR TORT  ////
//// (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT  ////
//// OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE         ////
//// POSSIBILITY OF SUCH DAMAGE.                                 ////
////                                                             ////
/////////////////////////////////////////////////////////////////////

`define SHA1_H0 32'h67452301
`define SHA1_H1 32'hefcdab89
`define SHA1_H2 32'h98badcfe
`define SHA1_H3 32'h10325476
`define SHA1_H4 32'hc3d2e1f0

`define SHA1_K0 32'h5a827999
`define SHA1_K1 32'h6ed9eba1
`define SHA1_K2 32'h8f1bbcdc
`define SHA1_K3 32'hca62c1d6

module sha1 (clk_i, rst_i, text_i, text_o, cmd_i, cmd_w_i, cmd_o);
  input    clk_i;   // global clock input
  input    rst_i;   // global reset input , active high

  input  [31:0]  text_i;  // text input 32bit
  output  [31:0]  text_o;  // text output 32bit

  input  [2:0]  cmd_i;  // command input
  input    cmd_w_i;// command input write enable
  output  [3:0]  cmd_o;  // command output(status)

  /*
    cmd
    Busy Round W R

    bit3 bit2  bit1 bit0
    Busy Round W    R

    Busy:
    0  idle
    1  busy

    Round:
    0  first round
    1  internal round

    W:
    0       No-op
    1  write data

    R:
    0  No-op
```

```
  1  read data

*/


    reg  [3:0]  cmd;
    wire  [3:0]  cmd_o;

    reg  [31:0]  text_o;

    reg  [6:0]  round;
    wire  [6:0]  round_plus_1;

    reg  [2:0]  read_counter;

    reg  [31:0]  H0,H1,H2,H3,H4;
    reg  [31:0]  W0,W1,W2,W3,W4,W5,W6,W7,W8,W9,W10,W11,W12,W13,W14;
    reg  [31:0]  Wt,Kt;
    reg  [31:0]  A,B,C,D,E;

    reg    busy;

    assign cmd_o = cmd;
    always @ (posedge clk_i)
    begin
      if (rst_i)
        cmd <= 'b0;
      else
      if (cmd_w_i)
        cmd[2:0] <= cmd_i[2:0];    // busy bit can't write
      else
      begin
        cmd[3] <= busy;      // update busy bit
        if (~busy)
          cmd[1:0] <= 2'b00;  // hardware auto clean R/W bits
      end
    end

    // Hash functions
wire [31:0] SHA1_f1_BCD,SHA1_f2_BCD,SHA1_f3_BCD,SHA1_Wt_1;
wire [31:0] SHA1_ft_BCD;
wire [31:0] next_Wt,next_A,next_C;
wire [159:0] SHA1_result;

assign SHA1_f1_BCD = (B & C) ^ (~B & D);
assign SHA1_f2_BCD = B ^ C ^ D;
assign SHA1_f3_BCD = (B & C) ^ (C & D) ^ (B & D);

assign SHA1_ft_BCD = (round < 'd21) ? SHA1_f1_BCD : (round < 'd41) ? SHA1_f2_BCD : (round < 'd61) ? SHA1_
```

```
    assign SHA1_Wt_1 = {W13 ^ W8 ^ W2 ^ W0};

assign next_Wt = {SHA1_Wt_1[30:0],SHA1_Wt_1[31]};  // NSA fix added
assign next_A = {A[26:0],A[31:27]} + SHA1_ft_BCD + E + Kt + Wt;
assign next_C = {B[1:0],B[31:2]};

assign SHA1_result   = {A,B,C,D,E};

assign round_plus_1 = round + 1;

//------------------------------------------------------------------
// SHA round
//------------------------------------------------------------------
always @(posedge clk_i)
begin
  if (rst_i)
  begin
    round <= 'd0;
    busy <= 'b0;

    W0  <= 'b0;
    W1  <= 'b0;
    W2  <= 'b0;
    W3  <= 'b0;
    W4  <= 'b0;
    W5  <= 'b0;
    W6  <= 'b0;
    W7  <= 'b0;
    W8  <= 'b0;
    W9  <= 'b0;
    W10 <= 'b0;
    W11 <= 'b0;
    W12 <= 'b0;
    W13 <= 'b0;
    W14 <= 'b0;
    Wt  <= 'b0;

    A <= 'b0;
    B <= 'b0;
    C <= 'b0;
    D <= 'b0;
    E <= 'b0;

    H0 <= 'b0;
    H1 <= 'b0;
    H2 <= 'b0;
    H3 <= 'b0;
    H4 <= 'b0;

  end
```

```
else
begin
  case (round)

  'd0:
    begin
      if (cmd[1])
      begin
        W0 <= text_i;
        Wt <= text_i;
        busy <= 'b1;
        round <= round_plus_1;

        case (cmd[2])
          1'b0:  // sha-1 first message
            begin
              A <= `SHA1_H0;
              B <= `SHA1_H1;
              C <= `SHA1_H2;
              D <= `SHA1_H3;
              E <= `SHA1_H4;

              H0 <= `SHA1_H0;
              H1 <= `SHA1_H1;
              H2 <= `SHA1_H2;
              H3 <= `SHA1_H3;
              H4 <= `SHA1_H4;
            end
          1'b1:  // sha-1 internal message
            begin
              H0 <= A;
              H1 <= B;
              H2 <= C;
              H3 <= D;
              H4 <= E;
            end
        endcase
      end
      else
      begin  // IDLE
        round <= 'd0;
      end
    end
  'd1:
    begin
      W1 <= text_i;
      Wt <= text_i;

      E <= D;
      D <= C;
```

```
      C <= next_C;
      B <= A;
      A <= next_A;

      round <= round_plus_1;
    end
  'd2:
    begin
      W2 <= text_i;
      Wt <= text_i;

      E <= D;
      D <= C;
      C <= next_C;
      B <= A;
      A <= next_A;

      round <= round_plus_1;
    end
  'd3:
    begin
      W3 <= text_i;
      Wt <= text_i;

      E <= D;
      D <= C;
      C <= next_C;
      B <= A;
      A <= next_A;

      round <= round_plus_1;
    end
  'd4:
    begin
      W4 <= text_i;
      Wt <= text_i;

      E <= D;
      D <= C;
      C <= next_C;
      B <= A;
      A <= next_A;

      round <= round_plus_1;
    end
  'd5:
    begin
      W5 <= text_i;
      Wt <= text_i;
```

```
    E <= D;
    D <= C;
    C <= next_C;
    B <= A;
    A <= next_A;

    round <= round_plus_1;
  end
'd6:
  begin
    W6 <= text_i;
    Wt <= text_i;

    E <= D;
    D <= C;
    C <= next_C;
    B <= A;
    A <= next_A;

    round <= round_plus_1;
  end
'd7:
  begin
    W7 <= text_i;
    Wt <= text_i;

    E <= D;
    D <= C;
    C <= next_C;
    B <= A;
    A <= next_A;

    round <= round_plus_1;
  end
'd8:
  begin
    W8 <= text_i;
    Wt <= text_i;

    E <= D;
    D <= C;
    C <= next_C;
    B <= A;
    A <= next_A;

    round <= round_plus_1;
  end
'd9:
  begin
    W9 <= text_i;
```

```
      Wt <= text_i;

      E <= D;
      D <= C;
      C <= next_C;
      B <= A;
      A <= next_A;

      round <= round_plus_1;
    end
  'd10:
    begin
      W10 <= text_i;
      Wt <= text_i;

      E <= D;
      D <= C;
      C <= next_C;
      B <= A;
      A <= next_A;

      round <= round_plus_1;
    end
  'd11:
    begin
      W11 <= text_i;
      Wt <= text_i;

      E <= D;
      D <= C;
      C <= next_C;
      B <= A;
      A <= next_A;

      round <= round_plus_1;
    end
  'd12:
    begin
      W12 <= text_i;
      Wt <= text_i;

      E <= D;
      D <= C;
      C <= next_C;
      B <= A;
      A <= next_A;

      round <= round_plus_1;
    end
  'd13:
```

```
  begin
    W13 <= text_i;
    Wt <= text_i;

    E <= D;
    D <= C;
    C <= next_C;
    B <= A;
    A <= next_A;

    round <= round_plus_1;
  end
'd14:
  begin
    W14 <= text_i;
    Wt <= text_i;

    E <= D;
    D <= C;
    C <= next_C;
    B <= A;
    A <= next_A;

    round <= round_plus_1;
  end
'd15:
  begin
    Wt <= text_i;

    E <= D;
    D <= C;
    C <= next_C;
    B <= A;
    A <= next_A;

    round <= round_plus_1;
  end
'd16,
'd17,
'd18,
'd19,
'd20,
'd21,
'd22,
'd23,
'd24,
'd25,
'd26,
'd27,
'd28,
```

```
        'd29,
        'd30,
        'd31,
        'd32,
        'd33,
        'd34,
        'd35,
        'd36,
        'd37,
        'd38,
        'd39,
        'd40,
        'd41,
        'd42,
        'd43,
        'd44,
        'd45,
        'd46,
        'd47,
        'd48,
        'd49,
        'd50,
        'd51,
        'd52,
        'd53,
        'd54,
        'd55,
        'd56,
        'd57,
        'd58,
        'd59,
        'd60,
        'd61,
        'd62,
        'd63,
        'd64,
        'd65,
        'd66,
        'd67,
        'd68,
        'd69,
        'd70,
        'd71,
        'd72,
        'd73,
        'd74,
        'd75,
        'd76,
        'd77,
        'd78,
```

```
    'd79:
      begin
        W0  <= W1;
        W1  <= W2;
        W2  <= W3;
        W3  <= W4;
        W4  <= W5;
        W5  <= W6;
        W6  <= W7;
        W7  <= W8;
        W8  <= W9;
        W9  <= W10;
        W10 <= W11;
        W11 <= W12;
        W12 <= W13;
        W13 <= W14;
        W14 <= Wt;
        Wt  <= next_Wt;

        E <= D;
        D <= C;
        C <= next_C;
        B <= A;
        A <= next_A;

        round <= round_plus_1;
      end
    'd80:
      begin
        A <= next_A + H0;
        B <= A + H1;
        C <= next_C + H2;
        D <= C + H3;
        E <= D + H4;
        round <= 'd0;
        busy <= 'b0;
      end
    default:
      begin
        round <= 'd0;
        busy <= 'b0;
      end
    endcase
  end
end


//----------------------------------------------------------------
// Kt generator
//----------------------------------------------------------------
```

```
always @ (posedge clk_i)
begin
  if (rst_i)
  begin
    Kt <= 'b0;
  end
  else
  begin
    if (round < 'd20)
      Kt <= `SHA1_K0;
    else
    if (round < 'd40)
      Kt <= `SHA1_K1;
    else
    if (round < 'd60)
      Kt <= `SHA1_K2;
    else
      Kt <= `SHA1_K3;
  end
end

//----------------------------------------------------------------------
// read result
//----------------------------------------------------------------------
always @ (posedge clk_i)
begin
  if (rst_i)
  begin
    text_o <= 'b0;
    read_counter <= 'b0;
  end
  else
  begin
    if (cmd[0])
    begin
      read_counter <= 'd4;  // sha-1   160/32=5
    end
    else
    begin
    if (~busy)
    begin
      case (read_counter)
        'd4:  text_o <= SHA1_result[5*32-1:4*32];
        'd3:  text_o <= SHA1_result[4*32-1:3*32];
        'd2:  text_o <= SHA1_result[3*32-1:2*32];
        'd1:  text_o <= SHA1_result[2*32-1:1*32];
        'd0:  text_o <= SHA1_result[1*32-1:0*32];
       default:text_o <= 'b0;
      endcase
      if (|read_counter)
```

```
          read_counter <= read_counter - 'd1;
      end
      else
      begin
        text_o <= 'b0;
      end
      end
    end
  end

endmodule
```

Chapter 11

Sha1 Forth code [30]

Forth requires words to be defined before they are used so the development of a SHA1 program is naturally bottom-up. But we tend to understand tasks top-down. We use literate programming to support this.

11.1 Things to know

A Forth string is implementation dependent but has been traditionally represented as a 1-byte count followed by up to 255 bytes of string.

```
+-------+------+------+------+------+-----+-----+
+ count | byte | byte | byte | .... | byte| byte|
+-------+------+------+------+------+-----+-----+
```

Blocks in the SHA algorithm are 512-bit strings, or 64 bytes.

SHA1 operates on 32-bit "words". Forth defines operations by defining "words". These concepts have nothing to do with each other.

The SHA algorithm is described using 32-bit words but the J1 cpu is a 16-bit implementation so we need to define some primitive words that operate on the data in 32-bit words. In particular, the SHA1 algorithm defines operations on words (section 3 of the standard) as:

```
Bitwise logical word operations

   X AND Y = bitwise logical "and" of X and Y.
   X OR Y  = bitwise logical "inclusive-or" of X and Y.
   X XOR Y = bitwise logical "exclusive-or" of X and Y.
   NOT Y   = bitwise logical "complement" of X.
```

The words **rot**, **-rot**, **OR**, **XOR**, **AND**, **swap** are standard Forth words defined as:

```
 rot ( x1 x2 x3 -- x2 x3 x1 )
-rot ( x1 x2 x3 -- x3 x1 x3 )
```

```
 or  ( x1 x2 -- x )
xor  ( x1 x2 -- x )
and  ( x1 x2 -- x )
swap ( x1 x2 -- x2 x1 )
```

The Forth "double" implementation of these are

— **logicalops** —

```
\ Double versions of bitwise and, or, xor

: DOR ( d1 d2 -- d3 )
  rot OR -rot OR swap ;
: DXOR ( d1 d2 -- d3 )
  rot XOR -rot XOR swap ;
: DAND ( d1 d2 -- d3 )
  rot AND -rot AND swap ;
```

———-

In order to understand how these words work you need to know that **d1** and **d2** are "double" (32-bit) words. This means that they are stored on the stack as 2 "single" (16-bit) words. So if we look at a stack trace of the operations of **DOR** we would see:

```
initial:  d1hi d1lo d2hi d2lo
    rot:  d1hi d2hi d2lo d1lo
     OR:  d1hi d2hi dlo
   -rot:  dlo  d1hi d2hi
     OR:  dlo  dhi
   swap:  dhi  dlo
```

11.2 The SHA1 standard [30]

11.2.1 Message Padding

The purpose of message padding is to make the total length of a padded message a multiple of 512 bits. SHA1 sequentially processes blocks of 512 bits when computing the message digest. The following specifies how this padding shall be performed. As a summary, a "1" followed by m "0"s followed by a 64-bit integer are appended to the end of the message to produce a padded message of length 512 * n. The 64-bit integer is the length of the original message. The padded message is then processed by the SHA1 as n 512-bit blocks.

Suppose a message has length $L < 2^{64}$. Before it is input to the SHA1, the message is padded on the right as follows:

a. "1" is appended. Example: if the original message is "01010000", this is padded to "010100001".

b. "0"s are appended. The number of "0"s will depend on the original length of the message. The last 64 bits of the last 512-bit block are reserved for the length L of the original message.
   Example: Suppose the original message is the bit string

```
01100001 01100010 01100011 01100100 01100101
```

After step (a) this gives

```
01100001 01100010 01100011 01100100 01100101 1
```

Since L = 40, the number of bits in the above is 41 and 407 "0"s are appended, making the total now 448. This gives (in hex)

```
61626364 65800000 00000000 00000000
00000000 00000000 00000000 00000000
00000000 00000000 00000000 00000000
00000000 00000000
```

c. Obtain the 2-word representation of L, the number of bits in the original message. If $L < 2^{32}$ then the first word is all zeros. Append these two words to the padded message. Example: Suppose the original message is as in (b). Then L = 40 (note that L is computed before any padding). The two-word representation of 40 is hex `00000000 00000028`. Hence the final padded message in hex is

```
61626364 65800000 00000000 00000000
00000000 00000000 00000000 00000000
00000000 00000000 00000000 00000000
00000000 00000000 00000000 00000028
```

The padded message will contain 16 * n words for some $n > 0$. The padded message is regarded as a sequence of n blocks M(1), M(2), first characters (or bits) of the message.

Note that this implementation assumes that the message is already properly padded.

11.2.2 Functions and Constants used

A sequence of logical functions $f(0)$, $f(1)$, ..., $f(79)$ is used in SHA1. Each $f(t)$, $0 \leq t \leq 79$, operates on 32-bit words B, C, D, and produces a 32-bit word as output. $f(t; B, C, D)$ is defined as follows:

```
f(t;B,C,D) = (B AND C) OR ((NOT B) AND D)       (  0 <= t <= 19 )
f(t;B,C,D) = B XOR C XOR D                      ( 20 <= t <= 39 )
f(t;B,C,D) = (B AND C) OR (B AND D) OR (C AND ) ( 40 <= t <= 59 )
f(t;B,C,D) = B XOR C XOR D                      ( 60 <= t <= 79 )
```

These are actually 3 distinct functions, defined in Forth as

— **logicalfns** —

```
: __F                ( dd dc db -- bc or b'd )
    2DUP D>R DAND 2SWAP DR> DINVERT DAND DOR ;

: __G                ( d c b -- bc or bd or cd )
    4DUP DAND D>R  DOR DAND DR>  DOR ;
```

```
: __H                  ( d c b -- d xor c xor b )
    DXOR DXOR ;
```

———-

A sequence of constant words $K(0)$, $K(1)$, ... $K(79)$ is used in SHA1. In hex these are given by

```
K(t) = 5A827999    (  0 <= t <= 19 )
K(t) = 6ED9EBA1    ( 20 <= t <= 39 )
K(t) = 8F1BBCDC    ( 40 <= t <= 59 )
K(t) = CA62C1D6    ( 60 <= t <= 79 )
```

The implementation uses these as explicit constants in the **transform** word which will be explained later.

11.2.3 Computing the message digest

Before processing any blocks, the H's are initialized as follows (in hex)

```
H0 = 67452301
H1 = EFCDAB89
H2 = 98BADCFE
H3 = 10325476
H4 = C3D2E1F0
```

These are set up as explicit contants used in **sha-init**, described below.

11.3 Forth Implementation

11.3.1 Storage

SIZE is a "double" location

So we create a **SIZE** "double" variable and a **Single-Bytee** variable.

— **SIZE** —

```
2VARIABLE SIZE
VARIABLE Single-Bytee
```

———-

The name **Message-Digest** is a constant pointer to a memory location of 5 32-bit cells to hold the 160 bit SHA1 hash result.

— **Message-Digest** —

```
\ Source program uses: CREATE Message-Digest   5 CELLS ALLOT
VHERE 5 CELLS VALLOT
XCONSTANT Message-Digest
```

———-

11.3.2 sha1

The top level word **sha1** expects the address of a Forth string.

The **sha1** function expects the address of a string at the top of stack. It returns the SHA1 sum of the string.

It calls **sha-init** for initialization. This will set up the initial bytes in **Message-Digest** to seed the algorithm. It has no final effect on the stack so the initial address argument to **sha1** is the top of stack.

We compute the count which computes (addr1 – addr2 n) where n is the length of the string at addr1 and addr2 points to the first byte. The word `u>d` extends the length n to be a double so the stack now looks like

```
( first-byte-of-string n 0 -- )
```

We then call **sha-update** to compute the SHA1.

It calls **sha-final** to clean up after itself.

It calls **.sha** to print the final result.

— **sha1** —

```
\ top level word
: sha1 ( string-xaddress )
  sha-init
  count u>d sha-update
  sha-final
.sha ;
```

————-

11.3.3 sha-init

This puts the **Message-Digest** address on the stack, pushes SHA1 constants onto the stack, and stores them into memory. So memory at **Message-Digest** now contains the 160-bit constant (in hex):

```
67 45 23 01 EF CD AB 89 98 BA DC FE 10 32 54 76 C3 D2 E1 F0
```

and the memory locate **SIZE** is set to (in hex)

```
00 00
```

— **sha-init** —

```
: SHA-INIT          ( -- )
    \  Initialize Message-Digest with starting constants.
    Message-Digest
        din 0x67452301 2OVER 2! CELL xn+
        din 0xEFCDAB89 2OVER 2! CELL xn+
        din 0x98BADCFE 2OVER 2! CELL xn+
```

```
        din 0x10325476 2OVER 2! CELL xn+
        din 0xC3D2E1F0 2SWAP 2!
    \  Zero bit count.
    0. SIZE 2! ;
```

———-

11.3.4 sha-update

do for each

— **sha-update** —

```
: SHA-UPDATE ( stringxaddr doublelen -- )
   4 needed
                        \ Transform 512-bit blocks of message.
    BEGIN               \ Transform Message-Block?
        size 2@         \ fetch upper cell (4 bytes) of SIZE variable
        0x1ff u>d DAND  \ fast modulo 512
        0x3 DRSHIFT     \ shift result 3 ( for example 511 >> 3 is 63 )
        D>R             \ save to return stack, name: modshiftcount
        0x40 U>D DR@ D- \ grab from return stack, 64 subtract modshiftcount
        2OVER DU> NOT   \ copy string count compare for loop

    WHILE               \ Store some of str&len, and transform.
                        \ duplicate string and count
        4DUP                ( xstr dlen xstr dlen)
                        \ 64 subtract dmodshiftcount
        0x40 U>D DR@ D-     ( xstr dlen xstr dlen dnewlen)
                        \ convert len,newlen to single width
        drop nip            ( xstr dlen xstr len newlen)
                        \ cut string to newlen
        /STRING             ( xstr dlen xnewstr (len-newlen) )
                        \ duplicate the difference, save to rstack
        U>D 2DUP D>R        ( xstr dlen xnewstr d(len-newlen) )
        4SWAP               ( xnewstr d(len-newlen) xstr dlen )
                        \ grab difference from rstack,
                        \ use it to get newlen in top cell
        DR> D-              ( xnewstr d(len-newlen) xstr dnewlen )
        Message-Block DR@ D+ ( xnewstr d(len-newlen) xstr
                             \ dnewlen xmessageaddr+modshiftcount )
        2SWAP               ( xnewstr d(len-newlen) xstr
                             \ xmessageaddr+modshiftcount dnewlen )
        drop                ( xnewstr d(len-newlen) xstr
                             \ xmessageaddr+modshiftcount newlen )
        MOVE                ( xnewstr d(len-newlen) )
        TRANSFORM           ( xnewstr d(len-newlen) )
        SIZE 2@             ( xnewstr d(len-newlen) dsize )
        0x40 U>D DR>        ( xnewstr d(len-newlen) dsize
                             \  0x40 0 dmodshiftcount)
```

```
    D-
    3 DLSHIFT D+ SIZE 2!  ." in" size 2@ d.
REPEAT
\  Save final fraction of input.
                    ( stringxaddr doublelen )
Message-Block DR> D+ ( stringxaddr doublelen
                    \ messageblockxaddr+modshiftcount )
2SWAP  2DUP          ( stringxaddr
                    \ messageblockxaddr+modshiftcount
                    \ doublelen doublelen )
D>R                  ( stringxaddr messageblockxaddr+modshiftcount
                    \ doublelen )
drop CMOVE  ( )      \ CMOVE
SIZE 2@ DR>  D2* D2* D2* D+ SIZE 2! ( )
;
```

———-

11.3.5 Fetch-Message-Digest

This puts 160 bits on the stack

— **Fetch-Message-Digest** —

```
: Fetch-Message-Digest   ( -- de dd dc db da )
    4 CELLS U>D Message-Digest D+  ( addr)
        2DUP 2@ 2SWAP CELL U>D d-  ( e addr)
        2DUP 2@ 2SWAP CELL U>D d-  ( e d addr)
        2DUP 2@ 2SWAP CELL U>D d-  ( e d c addr)
        2DUP 2@ 2SWAP CELL U>D d-  ( e d c b addr)
            2@ ;                   ( e d c b a)
```

———-

11.3.6 Add-to-Message-Digest

This adds the 160 bits on the top of the stack to the current SHA1 sum.

— **Add-to-Message-Digest** —

```
: Add-to-Message-Digest  ( de dd dc db da -- )
    Message-Digest                ( e d c b a addr)
        DTUCK 2+! CELL U>D D+      ( e d c b addr)
        DTUCK 2+! CELL U>D D+      ( e d c addr)
        DTUCK 2+! CELL U>D D+      ( e d addr)
        DTUCK 2+! CELL U>D D+      ( e addr)
             2+! ;                 ( )
```

———-

11.3.7 transform

— **transform** —

```
: TRANSFORM         ( -- )
    Fetch-Message-Digest    ( e d c b a)

    \  Do 80 Rounds of Complicated Processing.
    0x10  0x0 DO  D>R  6DUP __F din 0x5A827999 D+  DR>  I BLK0  MIX  LOOP
    0x14 0x10 DO  D>R  6DUP __F din 0x5A827999 D+  DR>  I BLK   MIX  LOOP
    0x28 0x14 DO  D>R  6DUP __H din 0x6ED9EBA1 D+  DR>  I BLK   MIX  LOOP
    0x3c 0x28 DO  D>R  6DUP __G din 0x8F1BBCDC D+  DR>  I BLK   MIX  LOOP
    0x50 0x3c DO  D>R  6DUP __H din 0xCA62C1D6 D+  DR>  I BLK   MIX  LOOP

    Add-to-Message-Digest ;
```

———-

11.3.8 blk0

BLK0 converts the first 16 cells of Message-Block to Work-Block. **BLK0** takes single-width index i, which is added to the base of Message-Block and two-fetched

— **blk0** —

```
: BLK0              ( i -- d )     \  Big Endian
    CELLS Message-Block rot xn+ 2@ ;
```

———-

11.3.9 blk

BLK converts the remaining cells of Message-Block to Work-Block. **BLK0** takes single-width index i, does some fancy XOR work folding into the same double. saves the final result to Message-Block, and also returns it (final double)

— **blk** —

```
: BLK               ( i -- d )
    DUP  0xd + 0xf AND CELLS Message-Block rot xn+ 2@
    2 pick 0x8 + 0xf AND CELLS Message-Block rot xn+ 2@  DXOR
    2 pick 0x2 + 0xf AND CELLS Message-Block rot xn+ 2@  DXOR
    2 pick       0xf AND CELLS Message-Block rot xn+ 2@  DXOR
    1 DLROTATE  \  This operation was added for SHA-1.
    2DUP 4 roll 15 AND CELLS Message-Block rot xn+ 2! ;
```

———-

11.3.10 mix

— **mix** —

```
\  temp = temp + (m + (a <<< 5)) + e
: MIX ( e d c b temp a m -- e d c b a )
    2SWAP 2DUP D>R                  ( e d c b temp m a)( R: a)
    0x5 DLROTATE d+ d+              ( e d c b temp)    ( R: a)
    2SWAP D>R  2SWAP D>R  2SWAP D>R  ( e temp)    ( R: a b c d)
    D+                              ( temp)      ( R: a b c d)
    \  e = d
       DR> 2SWAP                    ( e temp)      ( R: a b c)
    \  d = c
       DR> 2SWAP                    ( e d temp)      ( R: a b)
    \  c = (b <<< 30)
       DR> 0x1e DLROTATE            ( e d temp c)      ( R: a)
       2SWAP                        ( e d c temp)      ( R: a)
    \  b = a
       DR>                          ( e d c temp b)     ( R: )
    \  a = temp
       2SWAP                        ( e d c b a)
    ;
```

———-

11.3.11 sha-final

This allocates 9 bytes called **Final-Count**

— **Final-Count** —

```
VHERE 9 VALLOT
XCONSTANT Final-Count
```

———-

— **sha-final** —

```
: SHA-FINAL         ( -- )
    \  Save SIZE for final padding.

    \ final-count must be 64 bits, so we use 0 0 sizelow sizehi
    0 0 final-count 2!
    SIZE 2@
    Final-Count 4xn+ 2!

    \  Pad so SIZE is 64 bits less than a multiple of 512.
    Single-Bytee 0x80 2 pick 2 pick C!   ( xsingle-bytee )
    1 u>d SHA-UPDATE
```

```
    BEGIN  SIZE 2@ 0x1ff u>d DAND 0x1C0 u>d d= NOT WHILE
        Single-Bytee 0 2 pick 2 pick C!  1 u>d SHA-UPDATE
    REPEAT

    \ final-count is 64 bits (hence length of 8)
    Final-Count 8 u>d SHA-UPDATE
    ;
```

———-

11.3.12 sha

This **sha** word will write the final the SHA1 hash, on the screen by dumping the 20 bytes (160 bits) at location **Messsage-Digest**

— **sha** —

```
: .SHA
cr
." digest: "
   Message-Digest 0x20 dump  cr \  Display Message-Digest.
;
```

———-

— **sha1forth.fs** —

```
( SHA-160 Secure Hash Algorithm )

\ Based on code taken from:
\ http://www.forth.org.ru/~mlg/mirror/home.earthlink.net/~neilbawd/sha1.html
\ https://github.com/esromneb/Forth-Sha1-16-bit
\ as modified by Tim Daly

decimal

\ anew nielsha1

\getchunk{dshift}

\ number of bytes per memory address
4 CONSTANT CELL
: CELLS CELL * ;

\ real number of bytes per memory address
2 CONSTANT QEDCELL

\getchunk{SIZE}
```

```
\getchunk{Message-Digest}
20 vallot \ burn space for clean printing using dump

\ Source program uses: CREATE Message-Block   16 CELLS ALLOT
VHERE 16 CELLS VALLOT
XCONSTANT Message-Block

\getchunk{Final-Count}
\getchunk{logicalops}
\getchunk{stackops}
\getchunk{blk0}
\getchunk{blk}
\getchunk{logicalfns}
\getchunk{mix}
\getchunk{Fetch-Message-Digest}
\getchunk{Add-to-Message-Digest}
\getchunk{transform}
\getchunk{sha-init}
\getchunk{sha-update}
\getchunk{sha-final}
\getchunk{sha}
\getchunk{sha1}

hex

\ zero out variable memory.
\ some of this is taken care of in sha-init
2000 0 100 0 fill
```

11.4 Forth Word Dictionary

11.4.1 Standard Forth Words

The standard words mean:

```
."                      Write the characters to the terminal until the
                        matching trailing "

/STRING ( addr1 u1 n -- addr2 u2 ) Adjust the string at addr1 u1 by n
                                   characters. Return addr2=addr1+n
                                   with length u2 = u1-n

2! ( x1 x2 addr -- ) Stores two 16-bit words at addr

2@ ( addr -- x1 x2 ) Fetches two 16-bit words at addr

2DUP ( x1 x2 -- x1 x2 x1 x2 ) Dup top 2 cells on stack
```

```
2OVER ( x1 x2 x3 x4 -- x1 x2 x3 x4 x1 x2 ) Copy cell pair x1,x2 to stack top

2SWAP ( x1 x2 x3 x4 -- x3 x4 x1 x2 ) Exchange top two cell pairs

2VARIABLE <name> ( - ) Create a dictionary entry for name associated with
                       two cells of data space. Using <name> returns the
                       address of the first cell of the data space on
                       the stack.

4DUP ( x1 x2 x3 x4 -- x1 x2 x3 x4 x1 x2 x3 x4 ) Dup top 4 cells on stack

4xn+ ( addr1 -- addr2 ) Adds 4 to addr1 yielding addr2

ALLOT ( u -- )          Allocate u bytes of data space beginning
                        at the next available location.

CELL is the "word size" of the machine (2 bytes in this case)

CELLS ( n1 -- n2 )      Returns n2, the size in bytes of n1 cells

CONSTANT <name> ( x -- ) Create a dictionary entry for name
                         associated with value x

count ( addr1 -- addr2 u ) Returns the length u and the address of the
                           text portion of the string at addr1

cr                      Write a newline to the terminal

D- ( d1 d2 -- d3 ) Subtracts two signed double

D+ ( d1 d2 -- d3 ) Adds two signed double

D>R ( d -- ) (R: -- d ) move a double from the stack to the return stack

DO ( n1 n2 - ) Establish the loop parameters. This word expects the
               initial loop index n2 on top o the stack, with the
               limit value n1 beneath it. These values are removed
               from the stack and stored elsewhere, usually on the
               return stack, when DO is executed.

DU> ( ud1 ud2 -- flag ) Flag is TRUE if the unsigned double ud1 is greater
                        than the unsigned double ud2.

DR@ ( -- d ) (R: d -- d ) Copies the top double number on the return stack
                          to the data stack

DROP ( w -- ) Drops top cell off stack

din ( -- wd ) DIN removes the next word from the input stream, converts
```

```
             it to a 32-bit double number wd in the current base, and
             executes 2literal which leaves the number on the stack. So
             HEX DIN 12345678 ( -- 5678 1234 )

DRSHIFT ( xhi xlo u -- xhi2 xlo2 ) Shift the double u bits right

DUMP ( addr +n -- )      Display the contents o a memory region of length +n
                         starting at address addr

HERE ( - addr )          Push the address of the next available location
                         in data space onto the stack

MOVE ( addr1 addr2 u -- ) Copy u bytes at addr1 to the destination addr2

NIP ( x1 x2 -- x2 ) Drops the cell below the top of stack

pick ( +n -- x ) Place a copy of the nth entry on top of stack
                  This is 0-based so 0 pick is dup, 1 pick is over

u>d ( u -- d ) Converts an unsigned number to double on the stack
               Its definition is
   0 constant u>d

VARIABLE <name> ( - )  Create a dictionary entry for name associated with
                       one cell of data space. Using <name> returns the
                       address of the cell of the data space on the stack.

xn+ ( addr1 n -- addr2 ) adds signed integer n to addr1 to get addr2
```

11.4.2 Locally defined Forth words

These words have been defined specifically for this algorithm.

— **stackops** —

```
\DTUCK ( d1h1 d1lo d2hi d2low -- d2hi d2lo d1hi d1lo d2hi d2low )
\                         Place a copy of the double below the second
\                         double on the stack.
: DTUCK 2swap 2over ;

\6DUP ( x1 x2 x3 x4 x5 x6 -- x1 x2 x3 x4 x5 x6 x1 x2 x3 x4 x5 x6 )
\           Dup top 6 cells on stack
: 6DUP 4 xpick 4 xpick 4 xpick ;

\4SWAP ( x1 x2 x3 x4 x5 x6 x7 x8 -- x5 x6 x7 x8 x1 x2 x3 x4 )
\                        Exchange top 4 cell pairs
: 4SWAP 7 roll 7 roll 7 roll 7 roll ;

\ \\ this is the equivalent of +!
\ \\ : +! 2dup @ 3 pick + -rot ! drop ;
```

```
\ two-plus-store
: 2+! 2dup 2@ 4 xpick d+ 2swap 2! 2drop ;

: DLSHIFT DSHIFT ;
: DRSHIFT negate DSHIFT ;

: INVERT complement ;

: DINVERT complement swap complement swap ;

: DLROTATE           ( d1 n -- d2 )
    3DUP  DLSHIFT D>R  32 SWAP -  DRSHIFT DR>  DOR ;

hex
: LROTATE           ( x n -- x' )
  0 swap dlshift or ;

: Flip-Endian       ( 0102 -- 0201 )
    DUP 8 LROTATE 0xFF00 AND
    SWAP 8 LROTATE 0x00FF AND OR ;
decimal
```

———-

11.4.3 dshift

NOTE:This routine needs to be rewritten for the J1 processor

This is a general purpose shift word in assembly coded for Freescale HCS12/9S12. It logically i.e.,no sign extension shifts d1 accding to the value of n2. If n2 is positive, n1 is shifted left; if n2 is neg, n1 is shifted right. The absolute value of n2 determines the number of bits of shifting; unchecked error on overflow/underflow

— **dshift** —

```
CODE DSHIFT    ( d1 n2 -- d3 )
2 IND,Y LDD   \ D <- msword
4 IND,Y LDX   \ X <- lsword
0 IND,Y TST   \ test msbyte of n2; is n2 negative?
MI IF,        \ if n2 is negative, shift right:
    BEGIN,
      LSRA    \ shift right,preserve top bit, bot bit->carry INCORRECT
      RORB    \ rotate right,carry->top bit
      XGDX    \ D <- lsword, X <- msword, cond.codes unaffected
      RORA    \ shift right; carry->top.bit,bot bit->carry
      RORB    \ shift right; carry->top.bit
      XGDX    \ D <- msword, X <- lsword, cond.codes unaffected
      1 IND,Y INC
    GE UNTIL,
ELSE,         \ if n2 is positive, shift left
  1 IND,Y TST
```

```
  GT IF,      \ do nothing if index=0
    BEGIN,
      XGDX    \ D <- lsword, X <- msword, cond.codes unaffected
      LSLD    \ shift left,top bit->carry INCORRECT
      XGDX    \ D <- msword, X <- lsword, cond.codes unaffected
      ROLB    \ rotate left,carry->bottom bit
      ROLA    \ rotate left,carry->bottom bit
      1 IND,Y DEC
    LE UNTIL,
  THEN,
THEN,
2 ,+Y STD     ( d1.lsword\d3.msword -- ) \ save msword
2 IND,Y STX   ( -- d3 ) \ save lsword
RTS
END.CODE
```

———-

11.4.4 Dictionary of Algorithm Words

These words are locally defined

- DOR (d1 d2 – d3) double bitwise or
- DXOR (d1 d2 – d3) double bitwise xor
- DAND (d1 d2 – d3) double bitwise and
- DTUCK double-width tuck
- 6DUP duplicate 3 double numbers on the stack
- 4SWAP
- 2+! two-plus-store
- DLSHIFT double left shift
- DRSHIFT double right shift
- INVERT complement
- DINVERT double complement
- DLROTATE (d1 n – d2) double left rotate
- LROTATE (x n – x') left rotate
- Flip-Endian (0102 – 0201)
- BLK0 (i – d) Convert first 16 cells of Message-Block to Work-Block.

- BLK (i – d) Convert remaining cells of Message-Block to Work-Block.
- `__F` (dd dc db – bc or b'd)
- `__G` (d c b – bc or bd or cd)
- `__H` (d c b – d xor c xor b)
- MIX (e d c b temp a m – e d c b a) temp = temp + (m + (a ¡¡¡ 5)) + e
- Fetch-Message-Digest (– de dd dc db da)
- Add-to-Message-Digest (de dd dc db da –)
- TRANSFORM (–) Do 80 Rounds of Complicated Processing.
- SHA-INIT (–) Initialize Message-Digest with starting constants.
- SHA-UPDATE (stringxaddr doublelen –) Transform 512-bit blocks of message.
- SHA-FINAL (–)
- .SHA (–) Print the final SHA1 hash
- sha1 (string-xaddress) top level word

Chapter 12

Microsoft Related Papers

Abstract from Putnam[15]:

Datacenter workloads demand high computational complexities, flexibility, power efficiency, and low cost. It is challenging to improve all of these factos simultaneously. To advance datacenter capabilities beyond what commodity server designs can provide, we have designed and built a composable, reconfigurable fabric to accelerate portions of large-scale software services. Each instantiation of the fabric consists of a 6x8 2-D torus of high-end Stratix V FPGAs embedded into a half-rack of 48 machines. One FPGA is placed into each server, accessible through PCIe, and wired directly to other FPGAs with pairs of 10 Gb SAS cables.

In this paper, we describe a medium-scale deployment of this fabric on a bed of 1,632 servers, and measure its efficacy in accelerating the Bing web search engine. We describe the requirements and architecture of the system, detail the critical engineering challenges and solutions needed to make the system robust in the presence of failures, and measure the performance, power, and resilence of the system when ranking candidate documents. Under high load, the large-scale reconfigurable fabric improves the ranking throughput of each server by a factor of 95% for a fixed latency distribution – or, while maintaining equivalent throughput, reduces the tail latency by 29%.

Abstract from Kim[16]:

Data compression is crucial in large-scale storage servers to save both storage and network bandwidth, but it suffers from high computational cost. In this work, we present a high throughput FPGA based compressor as a PCIe accelerator to achieve CPU resource saving and high power efficiency. The proposed compressor is differentiated from previous hardware compressors by the following features:

1. Targeting Xpress9 algorithm, whose compression quality is comparable to the best Gzip implementation (level 9)

2. A scalable multi-engine architecture with various IP blocks to handle algorithmic complexity as well as to achieve high throughput

3. Supporting a heavily multi-threaded server environment with an asynchronous data transfer interface between the host and the accelerator

The implemented Xpress9 compressor on Altera Stratix V GS performs 1.6-2.4Gbps throughput with 7 engines on various compression benchmarks, supporting up to 128 thread contexts.

Abstract from Fowers[17]

Data compression techniques have been the subject of intense study over the past several decades due to exponential increases in the quantity of data stored and transmitted by computer systems. Compression algorithms are traditionally forced to make tradeoffs between throughput and compression quality (the ratio of original file size to compressed file size). FPGAs represent a compelling substrate for streaming applications such as data compression thanks to their capacity for deep pipelines and custom caching solutions. Unfortunately, data hazards in compression algorithms such as LZ77 inhibit the creation of deep pipelines without sacrificing some amount of compression quality. In this work we detail a scalable fully pipelined FPGA accelerator that performs LZ77 compression and static Huffman encoding at rates up to 5.6 GB/s. Furthermore, we explore tradeoffs between compression quality and FPGA area that allow the same throughput at a fraction of the logic utilization in exchange for moderate reductions in compression quality. Compared to recent FPGA compression studies, our emphasis on scalability gives our accelerator a 3.0x advantage in resource utilization at equivalent throughput and compression ratio.

Chapter 13

VivadoFPGA

The Xilinx Vivado software can be downloaded from the Xilinx website[54]. Registration is required.

To install the software

```
tar -zxf Xilinx_Vivado_SDK-WIN_2015.2_0626_1.tar.gz
cd Xilinx_Vivado_SDK-WIN_2015.2_0626_1
xsetup
agree to licenses
choose Vivado WebPACK
choose Next
choose Next (for destination directory)
choose Install
choose Get Free Licenses
click Connect Now
sign in
choose all four Activation Based Licenses
click Activeate Node-Locked License
on the Generate Node License popup, click Next
on the Review License Request, click Next
```

In this part, we use the Vivado to do some simple implementation of VHDl code, and try to run on the Altera's FPGA boards.

As can be seen in Figure 13.1, the code we use to illustrate the vivado workflow is simple. two input signals A and B, one output signal C. The transformation logic between them is: C <= A and B.

The code:

— ANDvhdl —

```
library IEEE;
use IEEE.STD_LOGIC_1164.ALL;

entity main is
For: (A:in STD_LOGIC;
```

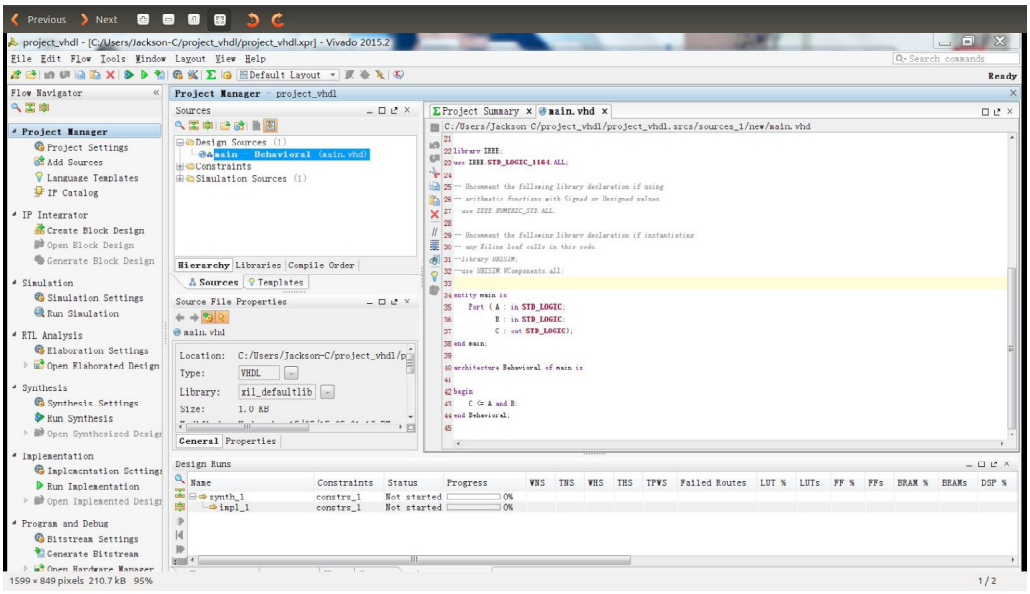


Figure 13.1: The vivado1

```
B:in STD_LOGIC;
C:out STD_LOGIC);
end main;

architecture Behavioral of main is

begin
C<=A and B;
end Behavioral;
```

As can be seen in Figure 13.2, we can find the waveform after simulating the vhdl code we presented above and it's easy to see the transformation logic behind the scenes.

Some Useful video links to use Vivado:

Vivado Design Flows Overview (v2013.1): From [59]

This video briefly describes the Vivado Design workflow. There are two Use Models:

1. Tcl scripted or GUI based use models
    - Run entire flow manually using Vivado Tcl Shell commands or scripts
    - Run entire flow with the press of a button using the Vivado IDE
2. Batch compilation style flow or project based flow
    - Manually manage all sources, design commands and configuration, and reporting using Tcl commands and scripts (Non-Project Mode)

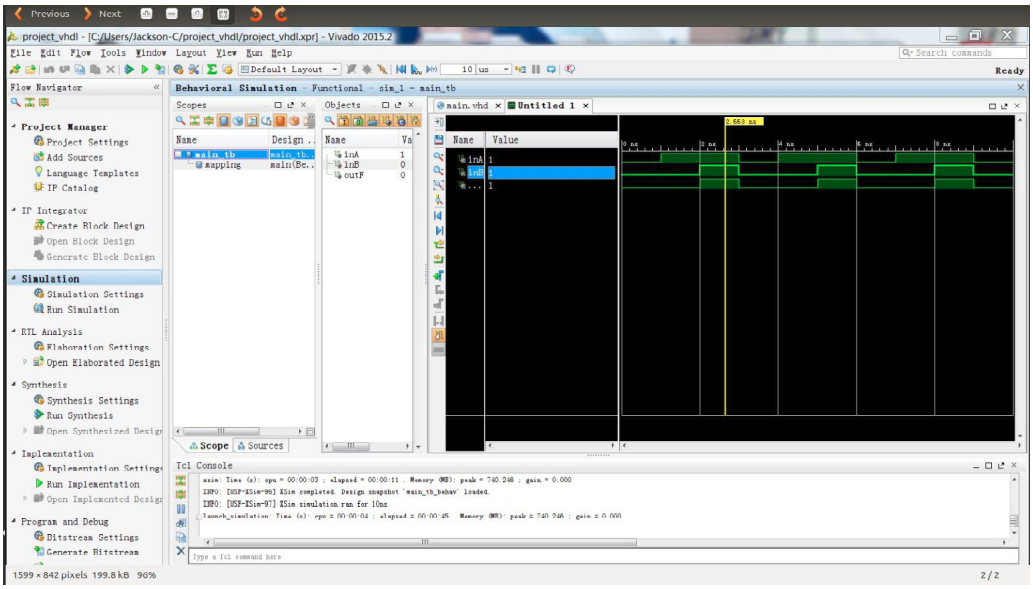


Figure 13.2: The vivado2

- Create a Project infrastructure on disk to manage entire design process and track status (Project Mode)

And some other things to be mentioned:

1. IP-Centric System-level Design Integration
   - Create IP subsystems with IP Integrator
   - Configure, validate and instantiate IP using the IP Catalog
2. System Design Entry through Hardware Validation Flows
   - Advanced design, analysis and process management capabilities
3. Flexible Use Models
   - Tcl accessible common data model throughout the flow
   - Project and compilation style flows
   - Support for third party software tools
4. Programming and Debugging Design in Hardware: From [60]:
   This video briefly explains and shows the steps to program and debug in Hardware using Vivado:
   (a) Connecting to the hardware and programming the FPGA
   (b) Setting up the ILA debug core trigger and probe simple compare conditions

   (c) Arming the ILA debug core and capture data in the waveform window

5. Logic Simulation: From [61]:
   This video shows how to simulate a design in Vivado IDE:
   (a) Simulation Settings
   (b) Launching Vivado Simulator
   (c) Waveform Viewer

And it lists some of the advantages that Vivado provides:

1. Easy to manage simulation sources and settings
   - automatically compile and simulate sources
2. Fully integrated simulator
   - powerful simulator engine (3x faster than ISE Simulator)
   - Common waveform viewer

And that could be part of the reasons why we choose Vivado rather than ISE.

Chapter 14

MAC

Here, we are using the tri-mode ethernet MAC v0.1.

1. Introduction

   The core of the Tri-mode ethernet MAC is designed from the ground up to be a compact, fast, no-frills core to faciliate streaming data from a widget to a connected computer. For example, the core only supports full-duplex operation in that it does not even look at the CRS (carrier-sense) and COL (collision detection) signals from the PHY (physical layer). And it will generate the ethernet and udp headers so we can simply give it data and it will take care of sending it for us.

2. Features

   Interfaces with the PHY using GMII running 10/100/1000 Mb/s. Support for RGMII is planned. Full-duplex support only. Raw ethernet frame generation, allowing a pure data input stream. Optional UDP/IP packet generation with automatic packetization and framentation of an input data stream. Input and output fifos decoupled from the core logic, so the clock rate of application logic is not tied to the speed of the ethernet link (barring bandwidth issues). Full core uses 288 Spartan 6 logic slices and 2 block RAMs. For comparison, the smallest Spartan 6 has 600 slices and 12 block RAMs. The largest Spartan 6 has 23,038 slices and 268 block RAMs.

3. Interfaces

   - Parameters

Name	Type	Description
USR_CLK_PERIOD	Integer	Period, in ns, of usr_clk. Needed to to generate a sutable clock for the mii management port (mdc) from usr_clk.
RX_CRC_CHECK	Boolean	If true, the CRC of incoming packets will be checked for accuracy. If false, no such check is performed.

Figure 14.1: The mac1

Name	Width	Direction	Description
usr_clk	1	I	User clock used to clock data into and out of the core through the user and management interfaces.
clk_125	1	I	125 MHz clock used to supply phy_GTX_CLK.
reset_n	1	I	Active-low reset. Resets all flops and buffers in the core.
debug	*	O	Various signals used during debugging.

Figure 14.2: mac2

- Clocks, etc.

4. Configuration

   Instead of implementing internal registers to indicate the source and destination MAC address, these values are simply ports into the core.

The following ports are part of the base MAC module and are always used:

Name	Width	Direction	Description
gmii	1	I	Indicate that the core should be communicate with the phy in GMII mode (i.e. 1Gbit/s). Otherwise MII mode (10/100Mbit/s) will be used. Unfortunately there doesn't appear to be a standard way to get the negotiated link speed from the PHY (why is this not in the 802.3 standard is beyond me).
promiscous	1	I	Indicate that the core should filter incoming packages to those with destination of src_mac_addr.
jumboframes	1	I	Indicates that jumbo frames are okay to send.
src_mac_addr	48	I	MAC address to use as the source of transmitted ethernet frames and the filter for what received frames to not discard when not in promiscous mode.
dst_mac_addr	48	I	MAC address to use as the destination of transmitted ethernet frames.
ethertype	16	I	EtherType/Length field for outgoing packets.
ifg	10	I	Number of cycles inserted between packets. Should be $\geq$ 0x0D.

Figure 14.3: mac3

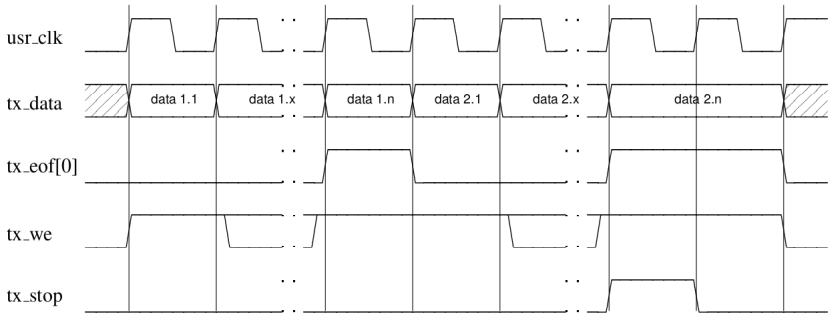


Figure 14.4: mac4

In Figure 14.4, we can see the timing diagram of two back to back 32-bit aligned packet transmissions, with the final word of the second packet being interrupted by a full input fifo.

5. Transmission

   The interface used to send packets/frames is a standard FIFO write interface with addition of an end-of-frame port (tx eo f) that is used to split incoming data into frames.

Name	Width	Direction	Description
tx_data	32	I	Data to be sent to the phy for transmission. Data is queued to be sent when tx_we is high and tx_stop is low. Following ethernet standards, bytes are sent in big endian order
tx_eof	4	I	Used to indicate which bytes in the word being written (tx_data) is the last of the frame. Because data is sent big endian, setting tx_eof[0] to 1 indicates that the entire 32-bit should be sent (and is the last word in this packet).
tx_we	1	I	Write enable for transmission. Queues tx_data to be sent to the phy when tx_stop is low.
tx_stop	1	O	Indicates that the input buffers are full and no more data can be queued for transmission.

Figure 14.5: mac5

   If the input fifo runs out of data while the MAC is sending a packet, an error condition will be raised and the packet will not be sent. Operating at 1Gbps, the PHY will transmit approximately 100MB/s from the input fifo. Therefore, if data word is supplied every clock, the user clock must be at least 25 MHz, an easy target for most FPGAs. Alternatively, if the user clock is faster, data need not be supplied on each clock. For example, a 100 MHz user clock means that once data is first written to the input fifo, the rest of the data can come at a rate as slow as one word every 4 clocks.

6. Reception

   The interface used to receive packets is a standard FIFO read interface, with the addition of an end-of-frame port (rx eo f).

Name	Width	Direction	Description
rx_data	32	O	Data received by the MAC from the phy. Valid when rx_dv is high.
rx_eof	4	O	Used to indicate that rx_data is the last word in the received frame. Mapped to rx_data just as tx_eof maps to tx_data.
rx_dv	1	O	Indicates that rx_data is valid data that was received by the MAC.
rx_ack	1	I	Acknowledges the receipt of rx_data and causes the MAC to move to the next received word.

Figure 14.6: mac6

7. Management

The following ports are used to read and write the MII management registers on the PHY. If they are left unconnected, the MII management module will be optimized away by the synthesis tools.

Name	Width	Direction	Description
miim_phyad	5	I	Management address of the PHY to communicate with.
miim_addr	5	I	Address of PHY register to read/write to.
miim_wdata	16	I	Data to write to the PHY register.
miim_we	1	I	Write Enable, write miim_wdata to the PHY register miim_addr.
miim_rdata	16	O	Data read from the PHY register.
miim_req	1	I	Sends a read request to the PHY for miim_addr.
miim_ack	1	O	Indicates that the requested operation (read or write) has been performed. If a read was requested, miim_rdata contains the data read from the PHY.

Figure 14.7: mac7

8. UDP/IP

When the UDP/IP Wrapper is used, the ethertype port is removed and the following configuration ports are added.

Name	Width	Direction	Description
src_ip	32	I	IP address to use as the source of trasmitted UDP/IP packets.
src_port	16	I	UDP port to use as the source of transmitted UDP/IP packets.
dst_ip	32	I	IP address to send UDP/IP packets to.
dst_port	16	I	UDP port to send UDP/IP packets to.
ttl	8	I	Value for the initial Time-To-Live field of UDP/IP packets.

Figure 14.8: mac8

9. PHY

The PHY ports are the standard GMII ports that should be tied directly to pins connected to an ethernet PHY.

Name	Width	Direction	Description
phy_TXD	8	O	These pins are the standard MII/GMII interface pins described numerous other places.
phy_TX_EN	1	O	
phy_TX_ER	1	O	
phy_TX_CLK	1	I	
phy_GTX_CLK	1	O	
phy_RXD	8	I	
phy_RX_DV	1	I	
phy_RX_ER	1	I	
phy_RX_CLK	1	I	
phy_MDC	1	O	
phy_MDIO	1	IO	

Figure 14.9: mac9

10. Reconciliation

    The reconcilation modules provides a common interface to the rest of the core regardless of the speed of the ethernet link. This is done by providing internal clocks to both the tx (int tx clk) and rx (int rx clk) modules which can be used to send data to the reconciliation layer eight bits a clock.

    If gmii is high we are operating at gigabit speeds and the phy sends and receives a full eight bits of data each 8ns. For transmission, clk 125 is used as both int tx clk and sent as phy GTXCLK, synchronizing all tranmission to that one 125 MHz clock. Likewise, all reception is synchronized to the 125 MHz phy RXCLK, which is sent as int rx clk.

    If gmii is low we are operating at 10 or 100 Mbits per second and only four bits of the databus to the phy is used. For transmission, the phy expects four bits every cycle of the phy supplied phy TXCLK; to maintain an eight bit interface with the rest of the mac, phy TXCLK is divided in half and sent as int tx clk. Likewise, the phy sends four bits every phy RXCLK, so this is divided in half and sent as int rx clk.

11. Architecture

    The MAC core is split up into three main components: tranmission, reception, and reconciliation. The transmission blocks, txfifo, tx engine, and crc gen, are responsible for taking user data and sending it to the reconcilia- tion module, which sends it to the ethernet phy. Likewise the recption blocks, rx usr if, rx pkt fifo, rxfifo, rx engine, and crc chk, are responsible for taking data from the reconciliation layer, throwing away bad frames, and presenting it to the user. The reconciliation layer handles with the GMII interface to the phy and deals with differences between 10/100Mbit operation and gigabit operation.

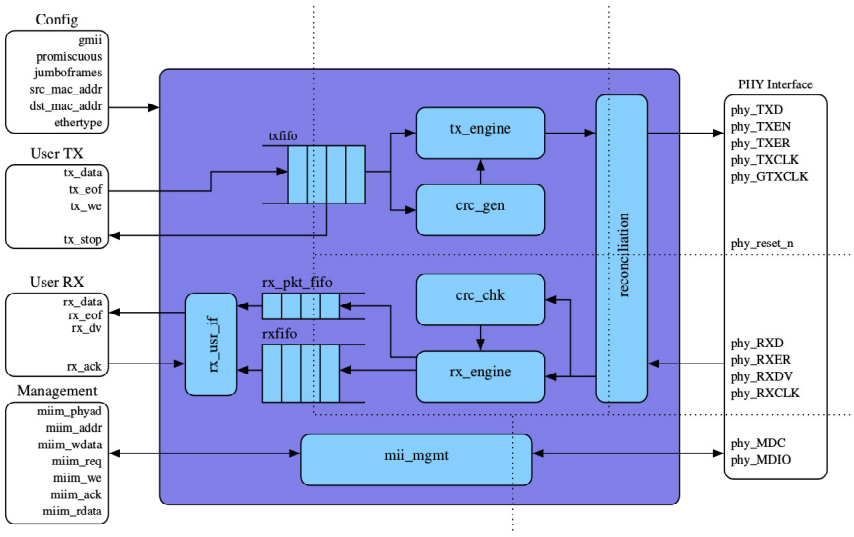


Figure 14.10: mac10

Chapter 15

crcgen

Here, we look into the $crc_gen.v$ code to see what it does.

— **inoutputs** —

```
module $crc_gen$
( input clk, input reset_n,
  input init,
  input [7:0] data,
  input rden,
  output [7:0] crc);
```

————-

1. inputs

   clk–clock signal $reset_n$–reset signal init–initialization signal data[7:0]–data array signal rden–$controlsignal$

2. outputs

   crc[7:0]–the crc array signal (cyclic redundancy check)

Chapter 16

rxrawv

Here, we look into the rx_raw module.

— **parameters** —

```
#(parameter $CKSM_CHK$=1)
```

———-

The parameters rx_raw used are:
$CKSM_CHK$: From mac.v RX_CKSM_CHECK

— **inoutputs** —

```
(input $usr_clk$,
 input $reset_n$,

 // config
 input        promiscuous,
 input        jumboframes,
 input [47:0] $mac_addr_filter$,
 output [31:0] $rx_count$,

 // phy interface
 input       $int_rx_clk$,
 input [7:0] $int_rx_din$,
 input       $int_rx_dv$,
 input       $int_rx_er$,

 // user interface
 output [31:0] $rx_data$,
 output        $rx_sof$,
 output        $rx_dv$,
 input         $rx_ack$,
```

```
output [17:0] debug);
```

———-

The inoutputs are:

usr_clk: From mac.v, usr_clk $reset_n$: From mac.v, $reset_n$

// config promiscuous: From mac.v, promisuous jumboframes: From mac.v, jumboframes mac_addr_filter: From mac.v, $rx_raw_mac_addr$ rx_count: To mac.v, rx_raw_count

// phy interface int_rx_clk: From mac.v, int_rx_clk int_rx_din: From mac.v, int_rx_din int_rx_dv: From mac.v, int_rx_dv int_rx_er: From mac.v, int_rx_er

// user interface rx_data: To mac.v, rx_raw_data rx_sof: To mac.v, rx_raw_sof rx_dv: To mac.v, rx_raw_dv rx_ack: From mac.v, rx_raw_ack

debug: To mac.v, rx_debug

— **crcgen** —

```
$
wire crc_init;
wire [7:0] crc_data;
wire crc_good;
generate if (CKSM_CHK == 1) begin
   crc_chk U_crc_chk
     (.clk(int_rx_clk), .reset_n(reset_n),
      .init(crc_init), .data(crc_data), .good(crc_good));
end
else begin
   assign crc_good = 1'b1;
end
endgenerate
$
```

———-

this part of code send data to crc_chk to generate the crc code for the data. And the crc code is on crc_good

— **rxpktfifo** —

```
$
wire rfq_we;
wire [13:0] rfq_din;
wire rfq_ready;
wire rfq_dv;
wire [13:0] rfq_dout;
wire rfq_ack;
wire rfq_empty;
wire rfq_full;

rx_pkt_fifo U_rx_pkt_fifo
  (.reset_n(reset_n), .int_rx_clk(int_rx_clk), .usr_clk(usr_clk),
   .we(rfq_we), .din(rfq_din), .ready(rfq_ready),
```

```
   .dv(rfq_dv), .dout(rfq_dout), .ack(rfq_ack),
   .fifo_empty(rfq_empty), .fifo_full(rfq_full));
$
```

———-

This part of code calls rx_pkt_fifo to check if fifo is ready and could do what we want it to do.

— **rxfifo** —

```
$
wire [35:0] rxff_din;
wire rxff_we;
wire rxff_almost_full;
wire [35:0] rxff_dout;
wire rxff_empty;
wire rxff_ack;
wire rxff_full;
rxfifo U_rxfifo
  (.rst(~reset_n),
   .wr_clk(int_rx_clk), .din(rxff_din), .wr_en(rxff_we),
   .full(rxff_full), .almost_full(rxff_almost_full),
   .rd_clk(usr_clk), .dout(rxff_dout), .rd_en(rxff_ack), .empty(rxff_empty));
$
```

———-

This part of code calls for the wrapper $rxfifo.v$ from the coregen of spartan3e.

— **rxengineraw** —

```
$
rx_engine_raw U_rx_engine_raw
  (.clk(int_rx_clk), .reset_n(reset_n),
   .promiscuous(promiscuous), .jumboframes(jumboframes),
   .mac_addr_filter(mac_addr_filter), .rx_count(rx_count),
   .int_rx_din(int_rx_din), .int_rx_dv(int_rx_dv), .int_rx_er(int_rx_er),
   .crc_init(crc_init), .crc_data(crc_data), .crc_good(crc_good),
   .rxff_din(rxff_din), .rxff_we(rxff_we), .rxff_almost_full(rxff_almost_full),
   .rfq_din(rfq_din), .rfq_we(rfq_we), .rfq_ready(rfq_ready));
$
```

———-

This part of code calls for rx_engine_raw to

— **rxusrif** —

```
$
rx_usr_if U_rx_usr_if
  (.clk(usr_clk), .reset_n(reset_n),
   .rxff_dout(rxff_dout), .rxff_empty(rxff_empty), .rxff_ack(rxff_ack),
   .rfq_dout(rfq_dout), .rfq_dv(rfq_dv), .rfq_ack(rfq_ack),
```

```
   .rx_data(rx_data), .rx_dv(rx_dv), .rx_sof(rx_sof), .rx_ack(rx_ack),
   .debug());
assign debug = { rfq_full, rfq_empty };
$
```

This part of code calls rx_usr_if to

Chapter 17

rxenginerawv

rx_engine_raw is part of the Reception blocks of MAC core.

— **inoutputs** —

```
(input clk, input $reset_n$,

 input        promiscuous,
 input        jumboframes,
 input [47:0] $mac_addr_filter$,
 output [31:0] $rx_count$,

 input [7:0] $int_rx_din$,
 input       $int_rx_dv$,
 input       $int_rx_er$,

 output       $crc_init$,
 output [7:0] $crc_data$,
 input        $crc_good$,

 output [35:0] $rxff_din$,
 output       $rxff_we$,
 input        $rxff_almost_full$,

 output [13:0] $rfq_din$,
 output        $rfq_we$,
 input         $rfq_ready$);
```

———-

input: promiscuous is from configuration
input: jummboframs is from configuration
input: mac_addr_filter is from configuration
input: int_rx_din, int_rx_dv and int_rx_er are from *reconciliation.v*
input: crc_good from $crc_chk.v$

Chapter 18

macv

Here, we look into the *mac.v* code to see what it does.

— parameters —

```
$
  module mac
#(parameter USR_CLK_PERIOD=5,
  parameter RX_CKSM_CHECK=1,
  parameter RAW_TXIF_COUNT=1,
  parameter RAW_RXIF_COUNT=1,
  parameter STREAM_TXIF_COUNT=0,
  parameter STREAM_RXIF_COUNT=0)
$
```

———-

USR_CLK_PERIOD : Period, in ns, of usr clk. Needed to to generate a sutable clock for the mii management port (mdc) from usr clk.

— inoutputs —

```
$
(input usr_clk, input clk_125, input reset_n,

 // config
 input        gmii,
 input        promiscuous,
 input        jumboframes,
 input [9:0]  ifg,

 // raw tx interface(s)
 input  [(RAW_TXIF_COUNT*32)-1:0] tx_raw_data,
 input  [RAW_TXIF_COUNT-1:0]      tx_raw_sof,
 input  [RAW_TXIF_COUNT-1:0]      tx_raw_we,
 output [RAW_TXIF_COUNT-1:0]      tx_raw_stop,
```

```
 output [(RAW_TXIF_COUNT*32)-1:0] tx_raw_count,

 // raw rx interface(s)
 input  [(RAW_RXIF_COUNT*48)-1:0] rx_raw_mac_addr,
 output [(RAW_RXIF_COUNT*32)-1:0] rx_raw_data,
 output [RAW_RXIF_COUNT-1:0]      rx_raw_sof,
 output [RAW_RXIF_COUNT-1:0]      rx_raw_dv,
 input  [RAW_RXIF_COUNT-1:0]      rx_raw_ack,
 output [(RAW_RXIF_COUNT*32)-1:0] rx_raw_count,

 // management interface
 input [0:4]   miim_phyad,
 input [0:4]   miim_addr,
 input [0:15]  miim_wdata,
 input         miim_req,
 input         miim_we,
 output        miim_ack,
 output [15:0] miim_rdata,

 // PHY interface
 output [7:0] phy_TXD,
 output       phy_TXEN,
 output       phy_GTXCLK,
 output       phy_TXER,
 input        phy_TXCLK,
 input        phy_RXCLK,
 input [7:0]  phy_RXD,
 input        phy_RXER,
 input        phy_RXDV,
 output       phy_RESET_N,

 output       phy_MDC,
 inout        phy_MDIO,

 output [31:0] debug);
$
```

Chapter 19

MACworkflow

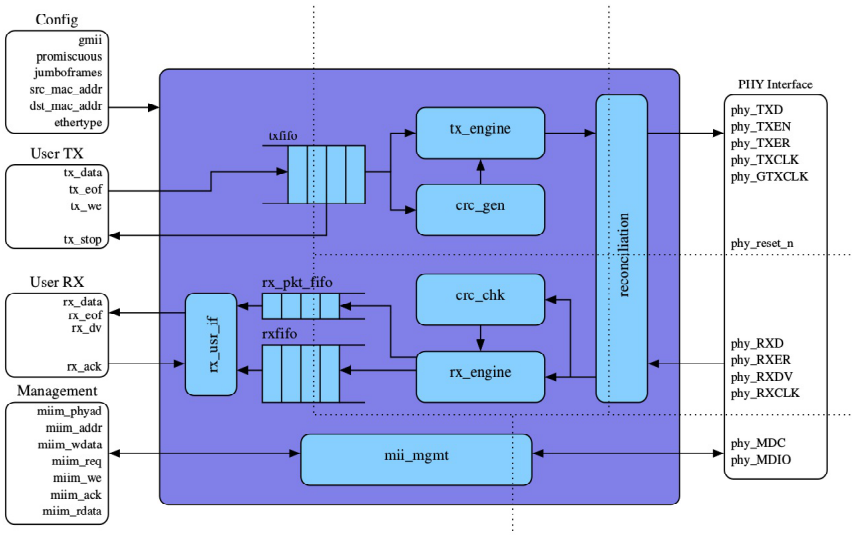


Figure 19.1: The mac10

This is the block diagram of the MAC core, which is very important in understanding how the MAC functions.

From the MAC chapter, we know that the MAC mainly has three parts: reception, reconciliation, and transmission.

The transmission part includes txfifo, tx_engine, and crc_gen, which takes the user data and send it to reconciliation module, which send it to ethernet phy.

The reception part includes rx_usr_if, rx_pkt_fifo, $rxfifo$, rx_engine, and crc_chk, which takes data from reconciliation, throwing away bad frames, and then present them to the user

The reconciliation part deals with GMII interface to phy.

TO use the MAC core, we can simply implement the configuration ports that MAC

presents to us, which is listed and explained as follows:

gmii: a flag that indicates whether the MAC core should be communicate with the phy in GMII mode or MII mode.

promiscous: a flag that indicates the MAC core should filter incoming packages to those with destination of src_mac_addr

src_mac_addr: this is the MAC address to use as the source of transmitted ethernet frames and the filter for what received frames to not discard when not in promiscous mode

dst_mac_addr: this is the MAC address to use as the destination of transmitted ethernet frames.

ethertype: the EtherType/Length field for outgoing packets

ifg: this is the number of cycles inserted between packets, should be $>= 0x0D$

Chapter 20

reconciliation

Here we look into the reconciliation layer, which deals with all the differences between MII and GMII (and eventually RGMII).

— **inoutputs** —

```
$
module reconciliation
(input clk_125, input reset_n,

 // decides whether we are in gmii or mii mode
 input gmii,

 input [7:0] int_tx_dout,
 input int_tx_en,
 input int_tx_er,
 output int_tx_clk,

 output [7:0] int_rx_din,
 output int_rx_dv,
 output int_rx_er,
 output int_rx_clk,

 output [7:0] phy_TXD,
 output       phy_TXEN,
 output       phy_TXER,
 output       phy_GTXCLK,
 input        phy_TXCLK,
 input  [7:0] phy_RXD,
 input        phy_RXDV,
 input        phy_RXER,
 input        phy_RXCLK
 );
$
```

———-

1. Transmission

   Generate int_tx_clk, which is what the mac is clocking data in on, and tx_clk which is what we are clocking data out on. If we are in MII mode, we ship 4 bits every phy_TXCLK, so we want the mac to clock the data in every other phy_TXCLK since the mac interface is 8 bits. We divide phy_TXCLK by two and send that as the int_tx_clk. Otherwise, we are in GMII mode and sending 8 bits every phy_GTXCLK, so send the full phy_GTXCLK as int_tx_clk.

   — transmiss —

```
$
wire mii_tx_clk;
greg mtc_reg(phy_TXCLK, ~mii_tx_clk, 1'b0, ~reset_n, 1'b1, mii_tx_clk);
BUFGMUX int_tx_clk_mux(.O(int_tx_clk), .I0(mii_tx_clk), .I1(clk_125), .S(gmii));

// Now generate tx_clk, which is used to clock the data out, this is
// simply clk_125 if gmii or phy_TXCLK if not.

wire tx_clk;
// BUFGMUX tx_clk_mux(.O(tx_clk), .I0(phy_TXCLK), .I1(clk_125), .S(gmii));
assign tx_clk = phy_TXCLK;


// Generate the output GTX clock to the phy, this will only be used in
// gmii mode.  We use an ODDR to delay and flip the clock so that
// the rising edge is sent in the middle of the data (sent below)
wire tmp0 = 1'b0;
wire tmp1 = 1'b1;
device_ODDR gtx_clk_out(.S(tmp0), .R(tmp0), .CE(tmp1),
                        .D0(1'b0), .C0(tx_clk), .D1(1'b1), .C1(~tx_clk),
                        .Q(phy_GTXCLK));

// now deal with the data.  For mii we alternate between nibbles.  For
// gmii we just blast the whole int_tx_dout each clock.
wire mii_tx_sel;
greg mts_reg(tx_clk, ~mii_tx_sel, ~int_tx_en, ~reset_n, 1'b1, mii_tx_sel);

wire [3:0] mii_txd;
gmux #(4, 1) mii_txd_mux(.d(int_tx_dout), .sel(mii_tx_sel), .z(mii_txd));

wire [7:0] next_txd;
gmux #(8, 1) txd_sel(.d({int_tx_dout, 4'h0, mii_txd}), .sel(gmii), .z(next_txd));

// TODO crossing clock domains... metastability??  Should be in phase...

greg #(8) TXD_reg(tx_clk, next_txd, 1'b0, ~reset_n, 1'b1, phy_TXD);
greg #(1) TXEN_reg(tx_clk, int_tx_en, 1'b0, ~reset_n, 1'b1, phy_TXEN);
```

```
greg #(1) TXER_reg(tx_clk, int_tx_er, 1'b0, ~reset_n, 1'b1, phy_TXER);
$
```

———-

2. Reception

   Again deal with the clocks first. If we are in MII mode, the phy sends 4 bits every phy_RXCLK, so the mac should be running at half phy_RXCLK to get 8 bits each clock tick. If we are in GMII mode, the phy sends 8 bits every phy_RXCLK, so we can just send the clock directly through.

   — **receptio** —

```
$
wire mii_rx_clk;
greg rcc_reg(phy_RXCLK, ~mii_rx_clk, 1'b0, ~reset_n, 1'b1, mii_rx_clk);
BUFGMUX int_rx_clk_mux(.O(int_rx_clk), .I0(mii_rx_clk), .I1(phy_RXCLK), .S(gmii));

// the data is a bit harder.  We start by registering the signals
// coming in the from the phy
wire [7:0] rx_din_0;
wire [3:0] rx_din_1;
wire rx_dv_0, rx_dv_1;
wire rx_er_0, rx_er_1;
greg #(8) rx_din_r0(phy_RXCLK, phy_RXD, 1'b0, ~reset_n, 1'b1, rx_din_0);
greg #(1) rx_dv_r0(phy_RXCLK, phy_RXDV, 1'b0, ~reset_n, 1'b1, rx_dv_0);
greg #(1) rx_er_r0(phy_RXCLK, phy_RXER, 1'b0, ~reset_n, 1'b1, rx_er_0);
$
```

   ———-

   the above signal are fine for gmii, but for mii, we need to hold them for two phy_RXCLK cycles, and not just any two, a cycle with int_rx_clk low and a cycle with int_rx_clk high. So we want to bring a new value in when int_rx_clk is high. To know what delay registers to use, we sample it when phy_RXDV goes high indicating a new frame. If int_rx_clk is high on new_frame is high, rx_din will be get it's first nibble when int_rx_clk is low.

   — **recept2** —

```
$
wire new_frame = ~rx_dv_0 & phy_RXDV;
wire started_on_low;
greg #(1) sol_reg(phy_RXCLK, mii_rx_clk, 1'b0, ~reset_n, new_frame, started_on_low);

greg #(4) rx_din_r1(phy_RXCLK, rx_din_0[3:0], 1'b0, ~reset_n, 1'b1, rx_din_1);
greg #(1) rx_dv_r1(phy_RXCLK, rx_dv_0, 1'b0, ~reset_n, 1'b1, rx_dv_1);
greg #(1) rx_er_r1(phy_RXCLK, rx_er_0, 1'b0, ~reset_n, 1'b1, rx_er_1);
```

```
wire [7:0] next_mii_rx_din;
wire next_mii_rx_dv;
wire next_mii_rx_er;
gmux #(10, 1) mii_rx_din_mux
  (.d({phy_RXER, phy_RXDV & ~new_frame, phy_RXD[3:0], rx_din_0[3:0],
       rx_er_1, rx_dv_1, rx_din_0[3:0], rx_din_1[3:0]}),
   .sel(started_on_low),
   .z({next_mii_rx_er, next_mii_rx_dv, next_mii_rx_din}));

wire [7:0] mii_rx_din;
wire mii_rx_dv;
wire mii_rx_er;
greg #(8) mii_rx_din_r1(phy_RXCLK, next_mii_rx_din, 1'b0, ~reset_n, ~mii_rx_clk, mii_rx_dir
greg #(1) mii_rx_dv_r1(phy_RXCLK, next_mii_rx_dv, 1'b0, ~reset_n, ~mii_rx_clk, mii_rx_dv);
greg #(1) mii_rx_er_r1(phy_RXCLK, next_mii_rx_er, 1'b0, ~reset_n, ~mii_rx_clk, mii_rx_er);

wire [7:0] next_int_rx_din;
wire next_int_rx_dv;
wire next_int_rx_er;
gmux #(10, 1) rx_mux
  (.d({rx_er_0, rx_dv_0, rx_din_0, mii_rx_er, mii_rx_dv, mii_rx_din}),
   .sel(gmii),
   .z({next_int_rx_er, next_int_rx_dv, next_int_rx_din}));

greg #(8) int_rx_din_reg(phy_RXCLK, next_int_rx_din, 1'b0, ~reset_n, 1'b1, int_rx_din);
greg #(1) int_rx_dv_reg(phy_RXCLK, next_int_rx_dv, 1'b0, ~reset_n, 1'b1, int_rx_dv);
greg #(1) int_rx_er_reg(phy_RXCLK, next_int_rx_er, 1'b0, ~reset_n, 1'b1, int_rx_er);

endmodule
$
```

---

register the output of all this craziness to maintain 125 MHz these registers act as the cross from the phy_RXCLK domain to the int_rx_clk domain. TODO − metastability issues.

Chapter 21

J1 Forth Level Network Code

The J1 cpu runs the programming language Forth. The file **basewords.fs** defines the forth words in terms of the J1 hardware.

21.1 English for forth programmers [64]

There is a difference between spelling a word and saying a word. In normal communication we do not ess-pee-ee-ell-ell words. Likewise we do not normally pronounce punctuation. (Period.) Sometimes it is necessary to spell for complete understanding but comprehension is generally easier when natural language is spoken.

A language may also have special signs `&` symbols which are normally "said", e.g., "`&`" and "`#`" are normally pronounced "and" and "number". Spelling often has very little relationship to the pronunciation, e.g., "lb" is "pound" and "cwt" is "hundredweight".

Forth is a language of natural English words and signs using machine oriented syntax for command and control of machines.

The so-called natural pronunciation of Forth words given in the Forth-79 and Forth-83 standard documents are mostly spellings. Experience has shown that Forth programs are easier to teach and understand when natural English words are used for the special signs.

An obvious example of this is "`#`". The standard documents give "sharp" as its natural pronunciation. This is patently wrong. The musical sharp sign is similar to it but different. The semantics of all occurrences of "`#`" in standard Forth words are connected with numbers. "`#`" should be said "number" and spelled "number-sign".

The standard specification of "`@`" is "value at <address>". It makes more sense to say "value" than "fetch" when we read it. Likewise "!" reads better as "set", which is what the function is called in other high-level languages. E.g., the body of the definition of "DEFINITIONS"

```
CURRENT @ CONTEXT !
```

reads naturally as

```
current value context set
```

This says What it does, not How it does it. This agrees with the Forth-83 standard document, which says that "descriptive" names are to be preferred to "procedural" names (section 4).

Reflection leads to "add" as the meaning of "+!". A fragment of code

```
0 #LINE !   1 #PAGE +!
```

reads naturally as

```
zero number-line set   one number-page add
```

The so-called natural pronunciation of the apostrophe "'" is given as "tick" in the Forth-83 standard document, ignoring descriptive and procedural names. A better word for this is "address". This also works well in compounds: from the Perry Line-Editor read

```
'START   'LINE   'CURSOR   'FIND
```

as

```
address-start  address-line  address-cursor  address-find
```

"compile-time-address" is a better name for "[']". In general say "compile-time-name" for "[name]".

The function of the dot or period "." in Forth is "display". The Forth word spelled "dot-quote" is used to display a message; the Forth word spelled "ABORT-quote" is used to abort with a message. They should be said "display-message" and "abort-message", which are perfect descriptions.

Forth has three common conventions for names within parentheses.

"(name)" is the default value of a vectored word. E.g.,

```
(CR)   (KEY)
```

"(name)" is used by "name". E.g.,

```
(.)
```

"(name)" is compiled by "name". E.g.,

```
(.'')   (ABORT'')   (LOOP)
```

Notice that the third case is a subset of the second.

All these uses can be covered by "primitive".

```
(CR)          primitive CR
(KEY)         primitive key
(.)           primitive display
(.'')          primitive display message
(ABORT'')      primitive abort message
(LOOP)        primitive loop
```

“,” is used to lay down values in the dictionary, and we say “lay” or “lay down” or “build” for this function.

Just as Forth is said to have been discovered, not invented, so the foregoing words were discovered in the order given. Having come so far, we would like to go the rest of the way.

“[“ is used to initiate interpretation, but “INTERPRET” is a word in the controlled word-set. We pronounce it “evaluate”.

A stumbling stone in learning Forth is the difference between “]”, “COMPILE”, and “[COMPILE]”.

If we think of “]” as “construct” we have a way to distinquish “]” from the other two. “COMPILE” will “compile” a defined word into the dictionary; “]” will do whatever is necessary to “construct” the dictionary, including defined words, literal values, logical structures, and anything else.

“[COMPILE]” is “compile-time compile”, which accurately describes what it does, compile the next word as a single word at compile-time, not run-time.

Some examples to show how this hangs together.

```
: ASCII  ( -- c ) BL WORD COUNT 1- ABORT'' ?''
   STATE @ IF [COMPILE] LITERAL THEN ; IMMEDIATE
```

“Define ASCII BL word count one-minus abort-message question-mark state value if compile-time-compile literal then. Immediate.”

Note that punctuation was not pronounced. Punctuation can be spelled when necessary for comprehension.

From the preceding paragraph we see how “(“ should be pronounced, i.e., “note”. Likewise “.(“ is “display-note”.

From an integer-ascii conversion definition:

```
... [ ASCII A 10 - ] LITERAL ...

``... evaluate ascii A 10 minus construct literal ...''
```

The prefix “C” is used in Forth to show byte-related operations. Just as “cwt” is pronounced “hundredweight” so “C@”, “C!”, and “C,” have the pronunciation “byte-value”, “byte-set”, and “byte-lay(down)”.

How about “possibly” or “maybe” for the question mark when it is part of a word, e.g., “maybe DUP” for “?DUP” ?

We can say “define” for “:” as we did above. The “;” can be silent punctuation, or we can use the Eastern “already” or Western “y’know” until some-one has a better suggestion.

Here is a summary of the suggested pronunciations.

```
#              number
@              value
!              set
+!             add
'              address
[']            compile-time address
.              display
.''             display message
```

```
ABORT''          abort message
(name)          primitive name
,               lay down, or lay
[               evaluate
]               construct
[COMPILE]       compile-time compile
(               note
.(              display note
?...            maybe ..., or possibly ...
:               define
;               already, or y'know.
```

The file **nuc.fs** implements the standard words from the Forth standard [64] so that the standard words work.

For example, the Forth standard defines the standard word `C@` as

```
6.1.0870   C@ ``c-fetch'' CORE
  ( c-addr -- char )
 Fetch the character stored at c-addr.  When the cell size is greater
 than character size, the unused high-order bits are all zeroes.
```

whereas **nuc.fs** implements this on the J1 as:

```
: c@    dup @ swap d# 1 and if d# 8 rshift else d# 255 and then ;
```

21.2 Connecting to the Hardware

We need to connect the port assignments in the verilog, such as in the file topj1.v, to the constants used in the forth code. The forth constants are in the ile hwwge.fs. So, for instance, the constant 6010 in topj1.v is identical to the name `rx_mac_filter` in hwwge.fs.

Next the bootstrap loader **boot.fs** loads the system from flash.

The **nuc.fs** file, mentioned above, implements standard forth words on the J1.

The **mac.fs** file contains the **mac-cold** word which handles reset of the MII device.

The **morse.fs** file, when loaded, causes the LEDs to flash morse code. There are 5 morse letters, (A, H, O, S, V) which mark the current state of the process.

- A means the mac interface is ready for the next 32 bits.
- S is the sleep state
- V is the vertical blank state of the camera

The alarms and sleep handling are in time.fs

The routine **mac-cold** in **mac.fs** resets the MAC interface.

The file **continuation.fs** handles saving and restoring program state.

The file **packet.fs** contains the words to handle packet construction, transmission, and reception.

The file **ip0.fs** initializes variables for the ip-address, subnet mask, dns, etc.

The file **defines_tcpip.fs** contains constants defining the offsets for various parts of a packet.

The file **defines_tcpip2.fs** contains constants defining the offsets for ethernet packets.
The file **arp.fs** sets up and manages the arp cache.
The file **ip.fs** handles IP ping/response, UDP checksums, and ICMP packets.
The file **dhcp.fs** handles DHCP packets and leases.
The file **spi.fs** handles the serial peripheral interface.
The file **flash.fs** handles flash memory.
The file **mt9v.fs** is the hardware interface for camera.
The file **wge.fs** handles the Willow Garage Ethernet camera protocol.
The file **newtcp.fs** handles low level TCP words.
The file **html.fs** constructs an HTML page
The file **http.fs** implements the HTTP protocol
The file **tcpservice.fs** handles the TCP general service scheme.
The file **ntp.fs** handles the network time protocol.
The file **syslog.fs** implements a syslog (RFC 5424)
The file **epa.fs** implements arbitrary precision arithmetic, along with the file **reference_epa.fs**.
The file **i2c** handles the i2c serial interface.
The file **rate.fs** is a rate reporting tool.
The file **testmt9v.fs** is a self-test tool for the camera.
The file **go** is a shell script to start the system.

21.3 main.fs

```
( Main for WGE firmware                      JCB 13:24 08/24/10)

\ warnings off require tags.fs

include crossj1.fs
meta
    : TARGET? 1 ;
    : ONBENCH 0 ;
    : SYSLOG 0 ;
    : DO-XORLINE 1 ;
    : build-debug? 1 ;
    : build-tcp? 0 ;

include basewords.fs
target
include hwwge.fs
include boot.fs
include doc.fs

4 org
module[ eveything"
include nuc.fs

create mac         6 allot
```

```
create serial      4 allot
create camera_name 40 allot

: net-my-mac mac dup @ swap 2+ dup @ swap 2+ @ ;

: halt  [char] # emit begin again ;

: alarm
    s" ** failed selftest: code " type hex2 cr
    halt
;

include version.fs
include parseversion.fs

: rapidflash
    time 2+ @ led ! ;
: morseflash ( code -- )
    time 2+ @ 2/ h# f and rshift invert led ! ;

include morse.fs
include time.fs
include mac.fs
include continuation.fs
include packet.fs
include ip0.fs
include defines_tcpip.fs
include defines_tcpip2.fs
include arp.fs
include ip.fs
include dhcp.fs

include spi.fs
include flash.fs

: hardreset
    true trig_reconf ! begin again ;

: softreset
    ['] emit-uart is emit
    sleep1 [char] a emit cr sleep1
    begin dsp h# ff and while drop repeat
    begin dsp d# 8 rshift while r> drop repeat
    dsp hex4 cr
    d# 0 >r
    sleep1 [char] b emit cr sleep1
;

include mt9v.fs
```

```
: setrouter ( router subnet -- )
    ip-subnetmask 2! ip-router 2!
    arp-reset
    net-my-ip arp-lookup drop arp-announce ;

: guess-mask ( ip -- )
    ip# 0.0.0.0 \ the world is my LAN
    ip# 0.0.0.0
    setrouter

    ip# 255.255.0.0 dand
    2dup ip# 10.0.0.0 d= if
        ip# 10.0.0.1
        ip# 255.255.248.0
        setrouter
    then
    2dup ip# 10.68.0.0 d= if
        ip# 10.68.0.1
        ip# 255.255.255.0
        setrouter
    then
    ip# 10.69.0.0 d= if
        ip# 10.69.0.11
        ip# 255.255.255.0
        setrouter
    then
;

: ip-addr! ( ip -- )
    2dup ip-addr 2@ d<> if
        2dup ip-addr 2!
        guess-mask
        arp-reset
    else
        2drop
    then
;

include wge.fs
build-tcp? [IF]
    include newtcp.fs
    include html.fs
    include http.fs
    include tcpservice.fs
[THEN]


( IP address formatting                      JCB 14:50 10/26/10)

: #ip1  h# ff and s>d #s 2drop ;
```

```
: #.    [char] . hold ;
: #ip2  dup #ip1 #. d# 8 rshift #ip1 ;
: #ip   ( ip -- c-addr u) dup #ip2 #. over #ip2 ;

( net-watchdog                                JCB 09:26 10/13/10)

2variable net-watchdog
: net-watch-reset
    d# 10000000. net-watchdog setalarm ;
: net-watch-expired?
    net-watchdog isalarm ;

: preip-handler
    begin
        enc-fullness
    while
        OFFSET_ETH_TYPE packet@ h# 800 =
        if
           dhcp-wait-offer
        then
        camera-handler
    repeat
;

: strlen ( addr -- u ) dup begin count 0= until swap - 1- ;

include ntp.fs

: haveip-handler
    begin
        enc-fullness
    while
        net-watch-reset
        arp-handler
        OFFSET_ETH_TYPE packet@ h# 800 =
        if
            d# 2 OFFSET_IP_DSTIP enc-offset enc@n net-my-ip d=
            if
                icmp-handler
                \ IP_PROTO_TCP ip-isproto if servetcp then
                \ ntp-handler
            then
            camera-handler
        then
        depth if .s cr then
        depth d# 6 u> if hardreset then
    repeat
;

: bench
```

```
    cbench
    d# 1000 >r \ iterations
    time@
    r@ negate begin
        \ d# 33. d# 101. 2d+ drop drop
        \ d# 33 d# 101 +1c drop
        \ d# 23 s>q d# 11 d# 17 qm*/ qdrop
        progress

        d# 1 + dup d# 0 =
    until drop
    time@
    decimal s" bench: " type
    2swap d- d# 6800 r> m*/ d# 600. d- <# # # [char] . hold #s #> type
    s"  cycles" type cr
;

ONBENCH [IF]
    : banner
        cr cr
        d# 64 0do [char] * emit loop cr
        s" J1 running" type cr
        cr

        s" Imager:  " type imagerversion @ hex4 cr
        s" PCB rev: " type pcb_rev @ . cr
        s" HDL rev: " type hdl_version @ hex4 cr
        s" FW rev:  " type version type
            s"  reports as " type version version-n hex d. decimal cr
        s" serial:  " type serial 2@ d. cr
        s" MAC:     " type net-my-mac mac-pretty cr
        cr
    ;
    : phy-report s" PHY status: " type d# 1 mac-mii@ hex4 cr ;

    create prev d# 4 allot
    : clocker
        time@ prev 2@ d- d# 1000000. d> if
            time@ prev 2!
            time@ hex8 space
            cr

            \ ntp-server arp-lookup if ntp-request then
        then
    ;
[ELSE]
    : phy-report ;
[THEN]

: .mii ( reg -- ) \ print MII reg value
```

```
    s" PHY" type dup . mac-mii@ hex4 ;

0 constant MIICONTROL
1 constant MIISTATUS
27 constant SPECIALS

: hackit
    \ MAC seems to need a long reset
    d# 0 MAC_reset ! sleep.1 d# 1 MAC_reset ! sleep.1
    \ Turn off auto-neg

    begin
         \ Register 0, Bit 12  = 0
         \ Register 0, Bit 13 = 1
         \  Register 0, Bit 8 = 1
        MIICONTROL mac-mii@
            h# efff and
            h# 2100 or
        snap MIICONTROL mac-mii!
        snap
        h# 8000 SPECIALS mac-mii!
        snap
        MIICONTROL .mii space MIISTATUS .mii space SPECIALS .mii cr
        sleep1
    again
;

SYSLOG [IF]
include syslog.fs
[THEN]

: get-dhcp
    net-my-mac xor mt9v-random d+ dhcp-xid!
    d# 0. dhcp-alarm setalarm

    d# 1000
    begin
        net-my-ip d0=
    while
        dhcp-alarm isalarm if
            dhcp-discover
            2* d# 8000 min
            dup d# 1000 m* dhcp-alarm setalarm
        then
        preip-handler
    repeat
    snap
    drop
    depth if begin again then
;
```

```
2variable ntp-alarm

: silence drop ;

: main
    decimal
    mt9v-cold
    atmel-cold
    atmel-cfg-rd
    atmel-id-rd

    ONBENCH [IF]
        banner
    [THEN]

    \ hackit

    net-my-mac mac-cold
    phy-report

    net-my-ip d0= if
        get-dhcp
    else
        net-my-ip guess-mask
    then

    arp-reset

    build-tcp? [IF]
        tcp-cold
    [THEN]

    ONBENCH [IF]
        dhcp-status
    [THEN]
    SYSLOG [IF]
        begin
            haveip-handler syslog-server arp-lookup 0=
        while
            sleep.1
        repeat
        s" syslog -> " type syslog-server ip-pretty cr
        syslog-cold ['] emit-syslog is emit
    [ELSE]
        ['] silence is emit
    [THEN]

    build-debug? [IF]
        s" booted serial://" type serial 2@ d.
```

```
        s" from " type
        h# 3ffe @ if s" mcs" else s" flash" then type
        s"  ip " type
        net-my-ip <# #ip #> type space
        s" xorline=" type
        [ DO-XORLINE ] literal hex1 space
        version type
        cr
        s" ready" type cr
    [THEN]

    \ net-my-ip arp-lookup drop arp-announce

    d# 1000000. ntp-alarm setalarm
    net-watch-reset
    begin
        \ clocker
        inframe invert if
            haveip-handler
        then
        mt9v-cycle
        net-watch-expired? if
            net-watch-reset
            mt9v-cold
            net-my-mac mac-cold
        then
        \ ntp-alarm isalarm if
        \     ntp-request
        \     d# 1000000. ntp-alarm setalarm
        \ then
    again

    halt
;
]module

0 org

code 0jump
    \ h# 3e00 ubranch
    main ubranch
    main ubranch
end-code

meta

hex


: create-output-file w/o create-file throw to outfile ;
```

```
s" j1.mem" create-output-file
:noname
    s" @ 20000" type cr
    4000 0 do i t@ s>d <# # # # # #> type cr 2 +loop
; execute

s" j1.bin" create-output-file
:noname 4000 0 do i t@ dup 8 rshift emit emit 2 +loop ; execute

s" j1.lst" create-output-file
d# 0
h# 2000 disassemble-block
```

21.4 packet.fs

```
( Packet construction, tx, rx                JCB 13:25 08/24/10)
module[ packet"

(tpd: two buffers are created of 1500 bytes. They are separated by
\ create incoming d# 1500 allot
\ create outgoing d# 1500 allot
[ 16384 512 - 1500 - ] constant incoming (tpd: 14374)
[ 16384 512 - 3000 - ] constant outgoing (tpd: 12872)

(tpd: incoming is a constant computed above.)

(tpd: add that constant to the top of the stack)

: enc-offset incoming + ;

: enc-c@    dup @ swap d# 1 and if d# 255 and else d# 8 rshift then ;

: enc@n ( n addr -- d0 .. dn )
    swap 0do dup @ swap 2+ loop drop ;

(tpd: add the incoming offset to the TOS and get its value)
: packet@ incoming + @ ;

(tpd: x -- loptr hiptr)
: packetd@ incoming + 2@ swap ;

: packetout-off           \  compute offset in output packet
    outgoing +
;

( words for constructing packet data         JCB 07:01 08/20/10)
variable writer
```

```
: enc-pkt-begin outgoing writer !  ;

: bump  ( n -- ) writer +! ;

: enc-pkt-c,    ( n -- )
    h# ff and
    writer @ d# 1 and if
        writer @ @ or
    else
        d# 8 lshift
    then
    writer @ !
    d# 1 bump
;

: enc-pkt-,     ( n -- ) writer @ ! d# 2 bump ;

: enc-pkt-d,    ( d -- ) enc-pkt-, enc-pkt-, ;

: enc-pkt-2,    ( n0 n1 -- ) swap enc-pkt-, enc-pkt-, ;

: enc-pkt-3,    rot enc-pkt-, enc-pkt-2, ;

: enc-pkt-,0    ( n -- ) 0do d# 0 enc-pkt-, loop ;

: enc-pkt-s,    ( caddr u -- )
    0do
        dup c@
        enc-pkt-c,
        1+
    loop
    drop
;

: enc-pkt-src ( n offset ) \ copy n words from incoming+offset
    incoming +
    swap 0do
        dup @ enc-pkt-,
        2+
    loop
    drop
;

: enc! ( n addr -- ) ! ;

: enc-pkt-complete ( -- length = set up TXST and TXND )
    writer @ outgoing -
;

(tpd: mac-ready will flash 'A' in morse code in the LEDs)
```

```
: mac-ready \ wait until MAC is ready for next 32 bits
    begin morse-a morseflash MAC_w_stop @ invert until ;

(tpd: MAC_w_stop  6200
      MAC_w_sof   6206 start of frame?
      MAC_w_0     6204
      MAC_w_we    6208
      MAC_w_count 620A )

: enc-send
    \ enc-pkt-begin
    \ d# 104 0do i enc-pkt-c, loop
    \ h# 800 outgoing d# 12 + !

    mac-ready

    d# 1 MAC_w_sof !
    writer @ 1+ h# fffe and outgoing -
    dup MAC_w_0 !
    d# 3 + h# fffc and
    outgoing d# 2 + + outgoing
    dup d# 2 + swap @ MAC_w_we !

    d# 0 MAC_w_sof !

    begin
        MAC_w_stop @ if
            mac-ready
        then
        dup@ MAC_w_0 !
        d# 2 +
        dup@ MAC_w_we !
        d# 2 + 2dup=
    until
    2drop

    \ MAC_w_count hex4 cr halt
;

(tpd: this is called in ip by ip-wrapup, icmp-handler and udp-checksum.
      this is called in newtcp by tcp-wrapup
: enc-checksum ( addr nwords -- sum )
    d# 0 swap
    0do
        over @       ( addr sum v )
        +1c
        swap 2+ swap
    loop
    nip
```

```
    invert
;

(tpd: this is called in main by the preip-handler and haveip-handler words)
: enc-fullness ( -- f )
    time 2+ @ d# 3 rshift led !
    \ no data => return false
    \ data+sof => handle it, return true
    \ data+no sof => ack, return false
    MAC_rd_dv @                             (tpd: MAC_rd_dv 6102)
    dup if
        MAC_rd_sof @ 0= if                  (tpd: MAC_rd_sof 6108)
            d# 1 MAC_rd_ack !               (tpd: MAC_rd_sof 610C)
            [char] ! emit
            drop d# 0 exit
        then
        MAC_rd_1 @ incoming !               (tpd: MAC_rd_sof 6104)
        \ N byte packet, N arrives.  Length takes 2 bytes,
        \ so (N+2) total bytes. Number of transactions is
        \ ((N+2)+3) / 4.  Subtract 1 for 1st transaction.
        \ So number of bytes is ((N+5)&~3)-4.

        MAC_rd_0 @ d# 1500 > if             (tpd: MAC_rd_0 6106)
            [char] * emit cr
            MAC_rd_sof @ hex4 cr            (tpd: MAC_rd_sof 6108)
            begin again
        then
        MAC_rd_0 @ d# 5 +                   (tpd: MAC_rd_0 6106)
        h# fffc and d# 4 -
        incoming 2+ swap bounds
        d# 1 MAC_rd_ack !                   (tpd: MAC_rd_ack 610C)
        begin
            MAC_rd_dv @ d# 0 = if           (tpd: MAC_rd_dv 6102)
                \ starved.  if no data after 4 clocks, bail
                noop noop noop noop
                MAC_rd_dv @ d# 0 = if       (tpd: MAC_rd_dv 6102)
                    [char] % emit
                    2drop drop d# 0
                    exit
                then
            then
            MAC_rd_0 @ over ! d# 2 +        (tpd: MAC_rd_0 6106)
            MAC_rd_1 @ over ! d# 2 +        (tpd: MAC_rd_1 6104)
            d# 1 MAC_rd_ack !               (tpd: MAC_rd_ack 610C)
            2dup=
        until
        2drop
    then
;
```

```
]module
```

Appendix A

DE1 gpio test

```
GPIO1 is the GPIO connector nearest outside edge of board.
GPIO1 layout is (pin 1 is near USB port, on inside edge of connector)
   pin 1           pin 2
   pin 3           pin 4
   pin 5           pin 6
   pin 7           pin 8
   pin 9           pin 10
   pin 11 (VCC5V)  pin 12 (GND)
   pin 13          pin 14
   pin 15          pin 16
   pin 17          pin 18
   pin 19          pin 20
   pin 21          pin 22
   pin 23          pin 24
   pin 25          pin 26
   pin 27          pin 28
   pin 29 (VCC3.3) pin 30 (GND)
   pin 31          pin 32
   pin 33          pin 34
   pin 35          pin 36
   pin 37          pin 38
   pin 39          pin 40

Wire from GPIO1 pin 1 to LED-diode+
     from LED-diode- to 180ohm resistor
     from 180ohm resistor to GPIO1 pin 11 (VCC 5V)
Pushing KEY[0] should turn OFF this LED

Wire from GPIO1 pin 2 to LED-diode+
     from LED-diode- to 180ohm resistor
     from 180ohm resistor to GPIO1 pin 11 (VCC 5V)
Pushing KEY[1] should turn OFF this LED

Wire from GPIO1 pin 3 to LED-diode+
```

```
     from LED-diode- to 180ohm resistor
     from 180ohm resistor to GPIO1 pin 11 (VCC 5V)
Pushing KEY[2] should turn OFF this LED

Wire from GPIO1 pin 4 to LED-diode+
     from LED-diode- to 180ohm resistor
     from 180ohm resistor to GPIO1 pin 11 (VCC 5V)
Pushing KEY[3] should turn ON this LED


library ieee;
use ieee.std_logic_1164.all;

ENTITY TPDblink IS
 PORT (
  KEY: in std_logic_vector(3 downto 0);
  GPIO_1: out std_logic_vector(35 downto 0));
end ENTITY TPDblink;

architecture TPDblinkarch of TPDblink is
 begin
  process(KEY)
   variable result: std_logic_vector(35 downto 0)
       := "111111111111111111111111111111111111";
   begin
 if KEY(0)='1' THEN
     result(0) := '1';
else
  result(0) := '0';
end if;
if KEY(1)='1' THEN
     result(1) := '1';
else
  result(1) := '0';
end if;
if KEY(2)='1' THEN
     result(2) := '1';
else
  result(2) := '0';
end if;
if KEY(3)='1' THEN
     result(3) := '0';
else
  result(3) := '1';
end if;
        GPIO_1 <= result;
  end process;
end architecture TPDblinkarch;

#*************************************************************
```

```
# This .sdc file is created by Terasic Tool.
# Users are recommended to modify this file to match users logic.
#**************************************************************

#**************************************************************
# Create Clock
#**************************************************************
create_clock -period 20.000ns [get_ports CLOCK_50]
create_clock -period 20.000ns [get_ports CLOCK2_50]
create_clock -period 20.000ns [get_ports CLOCK3_50]
create_clock -period 20.000ns [get_ports CLOCK4_50]

# for enhancing USB BlasterII to be reliable, 25MHz
create_clock -name {altera_reserved_tck} -period 40 {altera_reserved_tck}
set_input_delay -clock altera_reserved_tck -clock_fall 3 [get_ports altera_reserved_tdi]
set_input_delay -clock altera_reserved_tck -clock_fall 3 [get_ports altera_reserved_tms]
set_output_delay -clock altera_reserved_tck 3 [get_ports altera_reserved_tdo]

#**************************************************************
# Create Generated Clock
#**************************************************************
derive_pll_clocks



#**************************************************************
# Set Clock Latency
#**************************************************************



#**************************************************************
# Set Clock Uncertainty
#**************************************************************
derive_clock_uncertainty



#**************************************************************
# Set Input Delay
#**************************************************************



#**************************************************************
# Set Output Delay
#**************************************************************
```

```
#**************************************************************
# Set Clock Groups
#**************************************************************



#**************************************************************
# Set False Path
#**************************************************************



#**************************************************************
# Set Multicycle Path
#**************************************************************



#**************************************************************
# Set Maximum Delay
#**************************************************************



#**************************************************************
# Set Minimum Delay
#**************************************************************



#**************************************************************
# Set Input Transition
#**************************************************************



#**************************************************************
# Set Load
#**************************************************************




#============================================================
# Build by Terasic System Builder
#============================================================

set_global_assignment -name FAMILY "Cyclone V"
set_global_assignment -name DEVICE 5CSEMA5F31C6
```

```
set_global_assignment -name TOP_LEVEL_ENTITY "TPDblink"
set_global_assignment -name ORIGINAL_QUARTUS_VERSION 14.0
set_global_assignment -name LAST_QUARTUS_VERSION 14.1.0
set_global_assignment -name PROJECT_CREATION_TIME_DATE "21:01:14 FEBRUARY 27,2015"
set_global_assignment -name DEVICE_FILTER_PACKAGE FBGA
set_global_assignment -name DEVICE_FILTER_PIN_COUNT 896
set_global_assignment -name DEVICE_FILTER_SPEED_GRADE 6

#============================================================
# ADC
#============================================================
set_location_assignment PIN_AJ4 -to ADC_CS_N
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to ADC_CS_N
set_location_assignment PIN_AK4 -to ADC_DIN
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to ADC_DIN
set_location_assignment PIN_AK3 -to ADC_DOUT
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to ADC_DOUT
set_location_assignment PIN_AK2 -to ADC_SCLK
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to ADC_SCLK

#============================================================
# Audio
#============================================================
set_location_assignment PIN_K7 -to AUD_ADCDAT
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to AUD_ADCDAT
set_location_assignment PIN_K8 -to AUD_ADCLRCK
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to AUD_ADCLRCK
set_location_assignment PIN_H7 -to AUD_BCLK
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to AUD_BCLK
set_location_assignment PIN_J7 -to AUD_DACDAT
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to AUD_DACDAT
set_location_assignment PIN_H8 -to AUD_DACLRCK
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to AUD_DACLRCK
set_location_assignment PIN_G7 -to AUD_XCK
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to AUD_XCK

#============================================================
# CLOCK
#============================================================
set_location_assignment PIN_AF14 -to CLOCK_50
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to CLOCK_50
set_location_assignment PIN_AA16 -to CLOCK2_50
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to CLOCK2_50
set_location_assignment PIN_Y26 -to CLOCK3_50
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to CLOCK3_50
set_location_assignment PIN_K14 -to CLOCK4_50
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to CLOCK4_50

#============================================================
# SDRAM
```

```
#============================================================
set_location_assignment PIN_AK14 -to DRAM_ADDR[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_ADDR[0]
set_location_assignment PIN_AH14 -to DRAM_ADDR[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_ADDR[1]
set_location_assignment PIN_AG15 -to DRAM_ADDR[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_ADDR[2]
set_location_assignment PIN_AE14 -to DRAM_ADDR[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_ADDR[3]
set_location_assignment PIN_AB15 -to DRAM_ADDR[4]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_ADDR[4]
set_location_assignment PIN_AC14 -to DRAM_ADDR[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_ADDR[5]
set_location_assignment PIN_AD14 -to DRAM_ADDR[6]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_ADDR[6]
set_location_assignment PIN_AF15 -to DRAM_ADDR[7]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_ADDR[7]
set_location_assignment PIN_AH15 -to DRAM_ADDR[8]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_ADDR[8]
set_location_assignment PIN_AG13 -to DRAM_ADDR[9]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_ADDR[9]
set_location_assignment PIN_AG12 -to DRAM_ADDR[10]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_ADDR[10]
set_location_assignment PIN_AH13 -to DRAM_ADDR[11]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_ADDR[11]
set_location_assignment PIN_AJ14 -to DRAM_ADDR[12]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_ADDR[12]
set_location_assignment PIN_AF13 -to DRAM_BA[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_BA[0]
set_location_assignment PIN_AJ12 -to DRAM_BA[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_BA[1]
set_location_assignment PIN_AF11 -to DRAM_CAS_N
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_CAS_N
set_location_assignment PIN_AK13 -to DRAM_CKE
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_CKE
set_location_assignment PIN_AG11 -to DRAM_CS_N
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_CS_N
set_location_assignment PIN_AH12 -to DRAM_CLK
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_CLK
set_location_assignment PIN_AK6 -to DRAM_DQ[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_DQ[0]
set_location_assignment PIN_AJ7 -to DRAM_DQ[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_DQ[1]
set_location_assignment PIN_AK7 -to DRAM_DQ[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_DQ[2]
set_location_assignment PIN_AK8 -to DRAM_DQ[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_DQ[3]
set_location_assignment PIN_AK9 -to DRAM_DQ[4]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_DQ[4]
set_location_assignment PIN_AG10 -to DRAM_DQ[5]
```

```
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_DQ[5]
set_location_assignment PIN_AK11 -to DRAM_DQ[6]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_DQ[6]
set_location_assignment PIN_AJ11 -to DRAM_DQ[7]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_DQ[7]
set_location_assignment PIN_AH10 -to DRAM_DQ[8]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_DQ[8]
set_location_assignment PIN_AJ10 -to DRAM_DQ[9]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_DQ[9]
set_location_assignment PIN_AJ9 -to DRAM_DQ[10]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_DQ[10]
set_location_assignment PIN_AH9 -to DRAM_DQ[11]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_DQ[11]
set_location_assignment PIN_AH8 -to DRAM_DQ[12]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_DQ[12]
set_location_assignment PIN_AH7 -to DRAM_DQ[13]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_DQ[13]
set_location_assignment PIN_AJ6 -to DRAM_DQ[14]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_DQ[14]
set_location_assignment PIN_AJ5 -to DRAM_DQ[15]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_DQ[15]
set_location_assignment PIN_AB13 -to DRAM_LDQM
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_LDQM
set_location_assignment PIN_AE13 -to DRAM_RAS_N
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_RAS_N
set_location_assignment PIN_AK12 -to DRAM_UDQM
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_UDQM
set_location_assignment PIN_AA13 -to DRAM_WE_N
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to DRAM_WE_N

#============================================================
# I2C for Audio and Video-In
#============================================================
set_location_assignment PIN_J12 -to FPGA_I2C_SCLK
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to FPGA_I2C_SCLK
set_location_assignment PIN_K12 -to FPGA_I2C_SDAT
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to FPGA_I2C_SDAT

#============================================================
# SEG7
#============================================================
set_location_assignment PIN_AE26 -to HEX0[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX0[0]
set_location_assignment PIN_AE27 -to HEX0[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX0[1]
set_location_assignment PIN_AE28 -to HEX0[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX0[2]
set_location_assignment PIN_AG27 -to HEX0[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX0[3]
set_location_assignment PIN_AF28 -to HEX0[4]
```

```
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX0[4]
set_location_assignment PIN_AG28 -to HEX0[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX0[5]
set_location_assignment PIN_AH28 -to HEX0[6]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX0[6]
set_location_assignment PIN_AJ29 -to HEX1[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX1[0]
set_location_assignment PIN_AH29 -to HEX1[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX1[1]
set_location_assignment PIN_AH30 -to HEX1[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX1[2]
set_location_assignment PIN_AG30 -to HEX1[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX1[3]
set_location_assignment PIN_AF29 -to HEX1[4]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX1[4]
set_location_assignment PIN_AF30 -to HEX1[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX1[5]
set_location_assignment PIN_AD27 -to HEX1[6]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX1[6]
set_location_assignment PIN_AB23 -to HEX2[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX2[0]
set_location_assignment PIN_AE29 -to HEX2[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX2[1]
set_location_assignment PIN_AD29 -to HEX2[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX2[2]
set_location_assignment PIN_AC28 -to HEX2[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX2[3]
set_location_assignment PIN_AD30 -to HEX2[4]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX2[4]
set_location_assignment PIN_AC29 -to HEX2[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX2[5]
set_location_assignment PIN_AC30 -to HEX2[6]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX2[6]
set_location_assignment PIN_AD26 -to HEX3[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX3[0]
set_location_assignment PIN_AC27 -to HEX3[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX3[1]
set_location_assignment PIN_AD25 -to HEX3[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX3[2]
set_location_assignment PIN_AC25 -to HEX3[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX3[3]
set_location_assignment PIN_AB28 -to HEX3[4]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX3[4]
set_location_assignment PIN_AB25 -to HEX3[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX3[5]
set_location_assignment PIN_AB22 -to HEX3[6]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX3[6]
set_location_assignment PIN_AA24 -to HEX4[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX4[0]
set_location_assignment PIN_Y23 -to HEX4[1]
```

```
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX4[1]
set_location_assignment PIN_Y24 -to HEX4[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX4[2]
set_location_assignment PIN_W22 -to HEX4[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX4[3]
set_location_assignment PIN_W24 -to HEX4[4]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX4[4]
set_location_assignment PIN_V23 -to HEX4[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX4[5]
set_location_assignment PIN_W25 -to HEX4[6]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX4[6]
set_location_assignment PIN_V25 -to HEX5[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX5[0]
set_location_assignment PIN_AA28 -to HEX5[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX5[1]
set_location_assignment PIN_Y27 -to HEX5[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX5[2]
set_location_assignment PIN_AB27 -to HEX5[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX5[3]
set_location_assignment PIN_AB26 -to HEX5[4]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX5[4]
set_location_assignment PIN_AA26 -to HEX5[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX5[5]
set_location_assignment PIN_AA25 -to HEX5[6]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HEX5[6]

#============================================================
# IR
#============================================================
set_location_assignment PIN_AA30 -to IRDA_RXD
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to IRDA_RXD
set_location_assignment PIN_AB30 -to IRDA_TXD
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to IRDA_TXD

#============================================================
# KEY
#============================================================
set_location_assignment PIN_AA14 -to KEY[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to KEY[0]
set_location_assignment PIN_AA15 -to KEY[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to KEY[1]
set_location_assignment PIN_W15 -to KEY[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to KEY[2]
set_location_assignment PIN_Y16 -to KEY[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to KEY[3]

#============================================================
# LED
#============================================================
set_location_assignment PIN_V16 -to LEDR[0]
```

```
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to LEDR[0]
set_location_assignment PIN_W16 -to LEDR[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to LEDR[1]
set_location_assignment PIN_V17 -to LEDR[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to LEDR[2]
set_location_assignment PIN_V18 -to LEDR[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to LEDR[3]
set_location_assignment PIN_W17 -to LEDR[4]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to LEDR[4]
set_location_assignment PIN_W19 -to LEDR[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to LEDR[5]
set_location_assignment PIN_Y19 -to LEDR[6]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to LEDR[6]
set_location_assignment PIN_W20 -to LEDR[7]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to LEDR[7]
set_location_assignment PIN_W21 -to LEDR[8]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to LEDR[8]
set_location_assignment PIN_Y21 -to LEDR[9]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to LEDR[9]

#============================================================
# PS2
#============================================================
set_location_assignment PIN_AD7 -to PS2_CLK
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to PS2_CLK
set_location_assignment PIN_AD9 -to PS2_CLK2
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to PS2_CLK2
set_location_assignment PIN_AE7 -to PS2_DAT
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to PS2_DAT
set_location_assignment PIN_AE9 -to PS2_DAT2
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to PS2_DAT2

#============================================================
# SW
#============================================================
set_location_assignment PIN_AB12 -to SW[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to SW[0]
set_location_assignment PIN_AC12 -to SW[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to SW[1]
set_location_assignment PIN_AF9 -to SW[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to SW[2]
set_location_assignment PIN_AF10 -to SW[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to SW[3]
set_location_assignment PIN_AD11 -to SW[4]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to SW[4]
set_location_assignment PIN_AD12 -to SW[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to SW[5]
set_location_assignment PIN_AE11 -to SW[6]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to SW[6]
set_location_assignment PIN_AC9 -to SW[7]
```

```
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to SW[7]
set_location_assignment PIN_AD10 -to SW[8]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to SW[8]
set_location_assignment PIN_AE12 -to SW[9]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to SW[9]

#============================================================
# Video-In
#============================================================
set_location_assignment PIN_H15 -to TD_CLK27
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to TD_CLK27
set_location_assignment PIN_D2 -to TD_DATA[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to TD_DATA[0]
set_location_assignment PIN_B1 -to TD_DATA[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to TD_DATA[1]
set_location_assignment PIN_E2 -to TD_DATA[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to TD_DATA[2]
set_location_assignment PIN_B2 -to TD_DATA[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to TD_DATA[3]
set_location_assignment PIN_D1 -to TD_DATA[4]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to TD_DATA[4]
set_location_assignment PIN_E1 -to TD_DATA[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to TD_DATA[5]
set_location_assignment PIN_C2 -to TD_DATA[6]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to TD_DATA[6]
set_location_assignment PIN_B3 -to TD_DATA[7]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to TD_DATA[7]
set_location_assignment PIN_A5 -to TD_HS
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to TD_HS
set_location_assignment PIN_F6 -to TD_RESET_N
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to TD_RESET_N
set_location_assignment PIN_A3 -to TD_VS
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to TD_VS

#============================================================
# VGA
#============================================================
set_location_assignment PIN_B13 -to VGA_B[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_B[0]
set_location_assignment PIN_G13 -to VGA_B[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_B[1]
set_location_assignment PIN_H13 -to VGA_B[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_B[2]
set_location_assignment PIN_F14 -to VGA_B[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_B[3]
set_location_assignment PIN_H14 -to VGA_B[4]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_B[4]
set_location_assignment PIN_F15 -to VGA_B[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_B[5]
set_location_assignment PIN_G15 -to VGA_B[6]
```

```
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_B[6]
set_location_assignment PIN_J14 -to VGA_B[7]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_B[7]
set_location_assignment PIN_F10 -to VGA_BLANK_N
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_BLANK_N
set_location_assignment PIN_A11 -to VGA_CLK
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_CLK
set_location_assignment PIN_J9 -to VGA_G[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_G[0]
set_location_assignment PIN_J10 -to VGA_G[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_G[1]
set_location_assignment PIN_H12 -to VGA_G[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_G[2]
set_location_assignment PIN_G10 -to VGA_G[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_G[3]
set_location_assignment PIN_G11 -to VGA_G[4]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_G[4]
set_location_assignment PIN_G12 -to VGA_G[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_G[5]
set_location_assignment PIN_F11 -to VGA_G[6]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_G[6]
set_location_assignment PIN_E11 -to VGA_G[7]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_G[7]
set_location_assignment PIN_B11 -to VGA_HS
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_HS
set_location_assignment PIN_A13 -to VGA_R[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_R[0]
set_location_assignment PIN_C13 -to VGA_R[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_R[1]
set_location_assignment PIN_E13 -to VGA_R[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_R[2]
set_location_assignment PIN_B12 -to VGA_R[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_R[3]
set_location_assignment PIN_C12 -to VGA_R[4]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_R[4]
set_location_assignment PIN_D12 -to VGA_R[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_R[5]
set_location_assignment PIN_E12 -to VGA_R[6]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_R[6]
set_location_assignment PIN_F13 -to VGA_R[7]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_R[7]
set_location_assignment PIN_C10 -to VGA_SYNC_N
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_SYNC_N
set_location_assignment PIN_D11 -to VGA_VS
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to VGA_VS

#============================================================
# HPS
#============================================================
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_ADDR[0]
```

```
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_ADDR[1]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_ADDR[2]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_ADDR[3]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_ADDR[4]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_ADDR[5]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_ADDR[6]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_ADDR[7]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_ADDR[8]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_ADDR[9]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_ADDR[10]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_ADDR[11]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_ADDR[12]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_ADDR[13]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_ADDR[14]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_BA[0]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_BA[1]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_BA[2]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DM[0]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DM[1]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DM[2]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DM[3]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[0]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[1]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[2]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[3]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[4]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[5]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[6]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[7]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[8]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[9]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[10]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[11]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[12]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[13]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[14]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[15]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[16]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[17]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[18]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[19]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[20]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[21]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[22]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[23]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[24]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[25]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[26]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[27]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[28]
```

```
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[29]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[30]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_DQ[31]
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_CAS_N
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_CKE
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_CS_N
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_ODT
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_RAS_N
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_WE_N
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_RESET_N
set_instance_assignment -name IO_STANDARD "SSTL-15 CLASS I" -to HPS_DDR3_RZQ
set_instance_assignment -name IO_STANDARD "DIFFERENTIAL 1.5-V SSTL CLASS I" -to HPS_DDR3_DQS_P[0
set_instance_assignment -name IO_STANDARD "DIFFERENTIAL 1.5-V SSTL CLASS I" -to HPS_DDR3_DQS_N[0
set_instance_assignment -name IO_STANDARD "DIFFERENTIAL 1.5-V SSTL CLASS I" -to HPS_DDR3_DQS_P[1
set_instance_assignment -name IO_STANDARD "DIFFERENTIAL 1.5-V SSTL CLASS I" -to HPS_DDR3_DQS_N[1
set_instance_assignment -name IO_STANDARD "DIFFERENTIAL 1.5-V SSTL CLASS I" -to HPS_DDR3_DQS_P[2
set_instance_assignment -name IO_STANDARD "DIFFERENTIAL 1.5-V SSTL CLASS I" -to HPS_DDR3_DQS_N[2
set_instance_assignment -name IO_STANDARD "DIFFERENTIAL 1.5-V SSTL CLASS I" -to HPS_DDR3_DQS_P[3
set_instance_assignment -name IO_STANDARD "DIFFERENTIAL 1.5-V SSTL CLASS I" -to HPS_DDR3_DQS_N[3
set_instance_assignment -name IO_STANDARD "DIFFERENTIAL 1.5-V SSTL CLASS I" -to HPS_DDR3_CK_P
set_instance_assignment -name IO_STANDARD "DIFFERENTIAL 1.5-V SSTL CLASS I" -to HPS_DDR3_CK_N
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_ENET_GTX_CLK
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_ENET_INT_N
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_ENET_MDC
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_ENET_MDIO
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_ENET_RX_CLK
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_ENET_RX_DATA[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_ENET_RX_DATA[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_ENET_RX_DATA[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_ENET_RX_DATA[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_ENET_RX_DV
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_ENET_TX_DATA[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_ENET_TX_DATA[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_ENET_TX_DATA[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_ENET_TX_DATA[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_ENET_TX_EN
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_FLASH_DATA[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_FLASH_DATA[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_FLASH_DATA[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_FLASH_DATA[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_FLASH_DCLK
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_FLASH_NCSO
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_GPIO[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_GPIO[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_GSENSOR_INT
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_I2C1_SCLK
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_I2C1_SDAT
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_I2C2_SCLK
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_I2C2_SDAT
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_I2C_CONTROL
```

```
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_KEY
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_LED
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_SD_CLK
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_SD_CMD
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_SD_DATA[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_SD_DATA[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_SD_DATA[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_SD_DATA[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_SPIM_CLK
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_SPIM_MISO
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_SPIM_MOSI
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_SPIM_SS
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_UART_RX
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_UART_TX
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_USB_CLKOUT
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_USB_DATA[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_USB_DATA[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_USB_DATA[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_USB_DATA[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_USB_DATA[4]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_USB_DATA[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_USB_DATA[6]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_USB_DATA[7]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_USB_DIR
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_USB_NXT
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_USB_STP
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to HPS_CONV_USB_N

#============================================================
# GPIO_0, GPIO_0 connect to GPIO Default
#============================================================
set_location_assignment PIN_AC18 -to GPIO_0[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[0]
set_location_assignment PIN_Y17 -to GPIO_0[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[1]
set_location_assignment PIN_AD17 -to GPIO_0[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[2]
set_location_assignment PIN_Y18 -to GPIO_0[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[3]
set_location_assignment PIN_AK16 -to GPIO_0[4]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[4]
set_location_assignment PIN_AK18 -to GPIO_0[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[5]
set_location_assignment PIN_AK19 -to GPIO_0[6]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[6]
set_location_assignment PIN_AJ19 -to GPIO_0[7]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[7]
set_location_assignment PIN_AJ17 -to GPIO_0[8]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[8]
set_location_assignment PIN_AJ16 -to GPIO_0[9]
```

```
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[9]
set_location_assignment PIN_AH18 -to GPIO_0[10]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[10]
set_location_assignment PIN_AH17 -to GPIO_0[11]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[11]
set_location_assignment PIN_AG16 -to GPIO_0[12]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[12]
set_location_assignment PIN_AE16 -to GPIO_0[13]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[13]
set_location_assignment PIN_AF16 -to GPIO_0[14]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[14]
set_location_assignment PIN_AG17 -to GPIO_0[15]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[15]
set_location_assignment PIN_AA18 -to GPIO_0[16]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[16]
set_location_assignment PIN_AA19 -to GPIO_0[17]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[17]
set_location_assignment PIN_AE17 -to GPIO_0[18]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[18]
set_location_assignment PIN_AC20 -to GPIO_0[19]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[19]
set_location_assignment PIN_AH19 -to GPIO_0[20]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[20]
set_location_assignment PIN_AJ20 -to GPIO_0[21]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[21]
set_location_assignment PIN_AH20 -to GPIO_0[22]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[22]
set_location_assignment PIN_AK21 -to GPIO_0[23]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[23]
set_location_assignment PIN_AD19 -to GPIO_0[24]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[24]
set_location_assignment PIN_AD20 -to GPIO_0[25]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[25]
set_location_assignment PIN_AE18 -to GPIO_0[26]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[26]
set_location_assignment PIN_AE19 -to GPIO_0[27]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[27]
set_location_assignment PIN_AF20 -to GPIO_0[28]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[28]
set_location_assignment PIN_AF21 -to GPIO_0[29]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[29]
set_location_assignment PIN_AF19 -to GPIO_0[30]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[30]
set_location_assignment PIN_AG21 -to GPIO_0[31]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[31]
set_location_assignment PIN_AF18 -to GPIO_0[32]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[32]
set_location_assignment PIN_AG20 -to GPIO_0[33]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[33]
set_location_assignment PIN_AG18 -to GPIO_0[34]
```

```
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[34]
set_location_assignment PIN_AJ21 -to GPIO_0[35]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_0[35]

#============================================================
# GPIO_1, GPIO_1 connect to GPIO Default
#============================================================
set_location_assignment PIN_AB17 -to GPIO_1[0]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[0]
set_location_assignment PIN_AA21 -to GPIO_1[1]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[1]
set_location_assignment PIN_AB21 -to GPIO_1[2]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[2]
set_location_assignment PIN_AC23 -to GPIO_1[3]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[3]
set_location_assignment PIN_AD24 -to GPIO_1[4]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[4]
set_location_assignment PIN_AE23 -to GPIO_1[5]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[5]
set_location_assignment PIN_AE24 -to GPIO_1[6]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[6]
set_location_assignment PIN_AF25 -to GPIO_1[7]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[7]
set_location_assignment PIN_AF26 -to GPIO_1[8]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[8]
set_location_assignment PIN_AG25 -to GPIO_1[9]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[9]
set_location_assignment PIN_AG26 -to GPIO_1[10]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[10]
set_location_assignment PIN_AH24 -to GPIO_1[11]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[11]
set_location_assignment PIN_AH27 -to GPIO_1[12]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[12]
set_location_assignment PIN_AJ27 -to GPIO_1[13]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[13]
set_location_assignment PIN_AK29 -to GPIO_1[14]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[14]
set_location_assignment PIN_AK28 -to GPIO_1[15]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[15]
set_location_assignment PIN_AK27 -to GPIO_1[16]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[16]
set_location_assignment PIN_AJ26 -to GPIO_1[17]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[17]
set_location_assignment PIN_AK26 -to GPIO_1[18]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[18]
set_location_assignment PIN_AH25 -to GPIO_1[19]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[19]
set_location_assignment PIN_AJ25 -to GPIO_1[20]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[20]
set_location_assignment PIN_AJ24 -to GPIO_1[21]
```

```
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[21]
set_location_assignment PIN_AK24 -to GPIO_1[22]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[22]
set_location_assignment PIN_AG23 -to GPIO_1[23]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[23]
set_location_assignment PIN_AK23 -to GPIO_1[24]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[24]
set_location_assignment PIN_AH23 -to GPIO_1[25]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[25]
set_location_assignment PIN_AK22 -to GPIO_1[26]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[26]
set_location_assignment PIN_AJ22 -to GPIO_1[27]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[27]
set_location_assignment PIN_AH22 -to GPIO_1[28]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[28]
set_location_assignment PIN_AG22 -to GPIO_1[29]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[29]
set_location_assignment PIN_AF24 -to GPIO_1[30]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[30]
set_location_assignment PIN_AF23 -to GPIO_1[31]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[31]
set_location_assignment PIN_AE22 -to GPIO_1[32]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[32]
set_location_assignment PIN_AD21 -to GPIO_1[33]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[33]
set_location_assignment PIN_AA20 -to GPIO_1[34]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[34]
set_location_assignment PIN_AC22 -to GPIO_1[35]
set_instance_assignment -name IO_STANDARD "3.3-V LVTTL" -to GPIO_1[35]

#============================================================
# End of pin assignments by Terasic System Builder
#============================================================


set_global_assignment -name PARTITION_NETLIST_TYPE SOURCE -section_id Top
set_global_assignment -name PARTITION_FITTER_PRESERVATION_LEVEL PLACEMENT_AND_ROUTING -section_i
set_global_assignment -name PARTITION_COLOR 16764057 -section_id Top
set_global_assignment -name MIN_CORE_JUNCTION_TEMP 0
set_global_assignment -name MAX_CORE_JUNCTION_TEMP 85
set_global_assignment -name POWER_PRESET_COOLING_SOLUTION "23 MM HEAT SINK WITH 200 LFPM AIRFLOW
set_global_assignment -name POWER_BOARD_THERMAL_MODEL "NONE (CONSERVATIVE)"
set_global_assignment -name SOURCE_FILE TPDblink.qsf
set_global_assignment -name SDC_FILE TPDblink.SDC
set_global_assignment -name BDF_FILE TPDbnor.bdf
set_instance_assignment -name PARTITION_HIERARCHY root_partition -to | -section_id Top

\section{Chord Keyboard test}
\begin{verbatim}
```

GPIO1 is the GPIO connector nearest outside edge of board.
GPIO1 layout is (pin 1 is near USB port, on inside edge of connector)

Note that the VCC and GND pins are skipped in the GPIO number scheme.
This is certain to cause a bit of confusion.

PHYSICAL PIN NUMBERS		GPIO PIN NUMBERS	
pin 1	pin 2	pin 0	pin 1
pin 3	pin 4	pin 2	pin 3
pin 5	pin 6	pin 4	pin 5
pin 7	pin 8	pin 6	pin 7
pin 9	pin 10	pin 8	pin 9
pin 11 (VCC5V)	pin 12 (GND)		
pin 13	pin 14	pin 10	pin 11
pin 15	pin 16	pin 12	pin 13
pin 17	pin 18	pin 14	pin 15
pin 19	pin 20	pin 16	pin 17
pin 21	pin 22	pin 18	pin 19
pin 23	pin 24	pin 20	pin 21
pin 25	pin 26	pin 22	pin 23
pin 27	pin 28	pin 24	pin 25
pin 29 (VCC3.3)	pin 30 (GND)		
pin 31	pin 32	pin 26	pin 27
pin 33	pin 34	pin 28	pin 29
pin 35	pin 36	pin 30	pin 31
pin 37	pin 38	pin 32	pin 33
pin 39	pin 40	pin 34	pin 35

Chord Keyboard connector layout (DB25 connector)

```
  1   2   3   4   5   6   7   8   9   10   11   12   13
   14  15  16  17  18  19  20  21  22   23   24   25
```

```
pin  1 GND                  +------------------------+
pin  2 F2 FA                | F1 | F3 | F5 | F7 | F9 |
pin  3 F1 F9                +------------------------+
pin  4 T4 F8                | F1 | F3 | F5 | F7 | F9 |
pin  5 T3 F7                +------------------------+
pin  6 T2 F6          +----+
pin  7 GND            | T4 |
pin  8 Select Left    +----+
pin  9 Select Right   | T3 |
pin 11 +5V            +----+
pin 15 parity         | T2 |
pin 16    F3          +----+
pin 17    F4          | T1 |
pin 18 T1 F5          +----+
```

(NOTE: GPIO physical pin 3 == GPIO1 logical pin 2 == GPIO(2))

```
Wire from GPIO1 (physical pin 3,  logical 2)  to DB25 pin 2
Wire from GPIO1 (physical pin 4,  logical 3)  to DB25 pin 3
Wire from GPIO1 (physical pin 5,  logical 4)  to DB25 pin 4
Wire from GPIO1 (physical pin 6,  logical 5)  to DB25 pin 5
Wire from GPIO1 (physical pin 7,  logical 6)  to DB25 pin 6
Wire from GPIO1 (physical pin 9,  logical 8)  to DB25 pin 8
Wire from GPIO1 (physical pin 10, logical 9)  to DB25 pin 9
Wire from GPIO1 (physical pin 11, +5V)        to DB25 pin 11
Wire from GPIO1 (physical pin 12, GND)        to DB25 pin 1, DB25 pin 7
(NOTE: We don't skip 11, 12 as logical pins, see prior diagram)
Wire from GPIO1 (physical pin 19, logical 16) to DB25 pin 16
Wire from GPIO1 (physical pin 20, logical 17) to DB25 pin 17
Wire from GPIO1 (physical pin 21, logical 18) to DB25 pin 18
```

The keyboard has a SELECT LEFT (GPIO logical 8) and SELECT RIGHT (GPIO logical 9). We have to set 8 and 9 to read a key. In particular, to read F2, F1, T4, T3, T2, and T1

```
    GPIO_1(8) <= '0';
    GPIO_1(9) <= '1';
```

To read F3, F4, F5, F6, F7, F8, F9, and FA

```
    GPIO_1(8) <= '1';
    GPIO_1(9) <= '0';
```

Thus reading the key requires two physical reads.

```
library ieee;
use ieee.std_logic_1164.all;

ENTITY TPDblink IS
 PORT (
  LEDR: out std_logic_vector(9 downto 0);
  GPIO_1: inout std_logic_vector(35 downto 0));
end ENTITY TPDblink;

architecture TPDblinkarch of TPDblink is
 begin
  process(GPIO_1)
   -- the 10 LEDs on the board
   variable lights: std_logic_vector(9 downto 0) := "1111111111";
   constant lighton:  std_logic := '0';
   constant lightoff: std_logic := '1';
   -- F1 F3 F5 F7 F9 (upper row)
   -- F2 F4 F6 F8 FA (lower row)
   -- T4 T3 T2 T1 (thumb keys)
   -- keynamePinNumber: GPIO pin number
   constant F2FApin2:     Integer := 2;
   constant F1F9pin3:     Integer := 3;
```

```
    constant T4F8pin4:     Integer := 4;
    constant T3F7pin5:     Integer := 5;
    constant T2F6pin6:     Integer := 6;
    constant T1F5pin18:    Integer := 18;
    constant   F4pin17:    Integer := 17;
    constant   F3pin16:    Integer := 16;
    constant paritypin15:  Integer := 15;
    constant SELLEFTpin8:  Integer := 8;
    constant SELRIGHTpin9: Integer := 9;
    constant GNDpin1:      Integer := 12;
    constant GNDpin7:      Integer := 12;
    constant FiveVpin11:   Integer := 11;
    constant keydown: std_logic := '1';
    constant keyup:   std_logic := '0';

    begin
      -- GPIO_1(8) <= '0'; -- F2 F1 T4 T3 T2 T1
      -- GPIO_1(9) <= '1';
      GPIO_1(8) <= '1'; -- F3 F4 F5 F6 F7 F8 F9 FA
      GPIO_1(9) <= '0';
      if (GPIO_1(F1F9pin3) = keydown)
        then lights(0) := lighton; else lights(0) := lightoff; end if;
      if (GPIO_1(F2FApin2) = keydown)
        then lights(1) := lighton; else lights(1) := lightoff; end if;
      if (GPIO_1(F3pin16) = keydown)
        then lights(2) := lighton; else lights(2) := lightoff; end if;
      if (GPIO_1(F4pin17) = keydown)
        then lights(3) := lighton; else lights(3) := lightoff; end if;
      if (GPIO_1(T1F5pin18) = keydown)
        then lights(4) := lighton; else lights(4) := lightoff; end if;
      if (GPIO_1(T2F6pin6) = keydown)
        then lights(5) := lighton; else lights(5) := lightoff; end if;
      if (GPIO_1(T3F7pin5) = keydown)
        then lights(6) := lighton; else lights(6) := lightoff; end if;
      if (GPIO_1(T4F8pin4) = keydown)
        then lights(7) := lighton; else lights(7) := lightoff; end if;
      LEDR <= lights;
  end process;
end architecture TPDblinkarch;
```

Appendix B

IP Tables Examples[9]

B.0.1 Show firewall status

Type the following command as root:

```
# iptables -L -n -v
```

Inactive firewall output:

```
Chain INPUT (policy ACCEPT 0 packets, 0 bytes)
 pkts bytes target     prot opt in     out     source               destination
Chain FORWARD (policy ACCEPT 0 packets, 0 bytes)
 pkts bytes target     prot opt in     out     source               destination
Chain OUTPUT (policy ACCEPT 0 packets, 0 bytes)
 pkts bytes target     prot opt in     out     source               destination
```

active firewall output:

```
Chain INPUT (policy DROP 0 packets, 0 bytes)
 pkts bytes target     prot opt in     out     source               destination
    0     0 DROP       all  --  *      *       0.0.0.0/0            0.0.0.0/0
          state INVALID
  394 43586 ACCEPT     all  --  *      *       0.0.0.0/0            0.0.0.0/0
          state RELATED,ESTABLISHED
   93 17292 ACCEPT     all  --  br0    *       0.0.0.0/0            0.0.0.0/0
    1   142 ACCEPT     all  --  lo     *       0.0.0.0/0            0.0.0.0/0
Chain FORWARD (policy DROP 0 packets, 0 bytes)
 pkts bytes target     prot opt in     out     source               destination
    0     0 ACCEPT     all  --  br0    br0     0.0.0.0/0            0.0.0.0/0
    0     0 DROP       all  --  *      *       0.0.0.0/0            0.0.0.0/0
          state INVALID
    0     0 TCPMSS     tcp  --  *      *       0.0.0.0/0            0.0.0.0/0
          tcp flags:0x06/0x02 TCPMSS clamp to PMTU
    0     0 ACCEPT     all  --  *      *       0.0.0.0/0            0.0.0.0/0
          state RELATED,ESTABLISHED
    0     0 wanin      all  --  vlan2  *       0.0.0.0/0            0.0.0.0/0
```

```
    0     0 wanout     all  --  *      vlan2   0.0.0.0/0           0.0.0.0/0
    0     0 ACCEPT     all  --  br0    *       0.0.0.0/0           0.0.0.0/0
Chain OUTPUT (policy ACCEPT 425 packets, 113K bytes)
 pkts bytes target     prot opt in     out     source              destination
Chain wanin (1 references)
 pkts bytes target     prot opt in     out     source              destination
Chain wanout (1 references)
 pkts bytes target     prot opt in     out     source              destination
```

Where,

- -L : List rules.
- -v : Display detailed information.
- -n : Display IP address and port in numeric format

B.0.2 Firewall with line numbers

```
# iptables -n -L -v --line-numbers
```

Sample outputs:

```
Chain INPUT (policy DROP)
num  target     prot opt source               destination
1    DROP       all  --  0.0.0.0/0            0.0.0.0/0
    state INVALID
2    ACCEPT     all  --  0.0.0.0/0            0.0.0.0/0
    state RELATED
,ESTABLISHED
3    ACCEPT     all  --  0.0.0.0/0            0.0.0.0/0
4    ACCEPT     all  --  0.0.0.0/0            0.0.0.0/0
Chain FORWARD (policy DROP)
num  target     prot opt source               destination
1    ACCEPT     all  --  0.0.0.0/0            0.0.0.0/0
2    DROP       all  --  0.0.0.0/0            0.0.0.0/0
    state INVALID
3    TCPMSS     tcp  --  0.0.0.0/0            0.0.0.0/0
    tcp flags:0x06/0x02 TCPMSS clamp to PMTU
4    ACCEPT     all  --  0.0.0.0/0            0.0.0.0/0
    state RELATED,ESTABLISHED
5    wanin      all  --  0.0.0.0/0            0.0.0.0/0
6    wanout     all  --  0.0.0.0/0            0.0.0.0/0
7    ACCEPT     all  --  0.0.0.0/0            0.0.0.0/0
Chain OUTPUT (policy ACCEPT)
num  target     prot opt source               destination
Chain wanin (1 references)
num  target     prot opt source               destination
Chain wanout (1 references)
num  target     prot opt source               destination
```

You can use line numbers to delete or insert new rules into the firewall.

B.0.3 INPUT or OUTPUT chain rules

```
# iptables -L INPUT -n -v
# iptables -L OUTPUT -n -v --line-numbers
```

B.0.4 Stop / Start / Restart the Firewall

If you are using CentOS / RHEL / Fedora Linux, enter:

```
# service iptables stop
# service iptables start
# service iptables restart
```

You can use the iptables command itself to stop the firewall and delete all rules:

```
# iptables -F
# iptables -X
# iptables -t nat -F
# iptables -t nat -X
# iptables -t mangle -F
# iptables -t mangle -X
# iptables -P INPUT ACCEPT
# iptables -P OUTPUT ACCEPT
# iptables -P FORWARD ACCEPT
```

Where,

- -F : Delete all the rules.
- -X : Delete chain.
- -t table_name : Select table (called nat or mangle) and delete/flush rules.
- -P : Set the default policy.

B.0.5 Delete Firewall Rules

To display line number along with other information for existing rules, enter:

```
# iptables -L INPUT -n --line-numbers
# iptables -L OUTPUT -n --line-numbers
# iptables -L OUTPUT -n --line-numbers | less
# iptables -L OUTPUT -n --line-numbers | grep 202.54.1.1
```

You will get the list of IP. Look at the number on the left, then use number to delete it. For example delete line number 4, enter:

```
# iptables -D INPUT 4
```

OR find source IP 202.54.1.1 and delete from rule:

```
# iptables -D INPUT -s 202.54.1.1 -j DROP
```

Where,

- -D : Delete one or more rules from the selected chain

B.0.6 Insert Firewall Rules

To insert one or more rules in the selected chain as the given rule number use the following syntax. First find out line numbers, enter:

```
# iptables -L INPUT -n line-numbers
```

Sample outputs:

```
Chain INPUT (policy DROP)
num  target     prot opt source               destination
1    DROP       all  --  202.54.1.1           0.0.0.0/0
2    ACCEPT     all  --  0.0.0.0/0            0.0.0.0/0
     state NEW,ESTABLISHED
```

To insert rule between 1 and 2, enter:

```
# iptables -I INPUT 2 -s 202.54.1.2 -j DROP
```

To view updated rules, enter:

```
# iptables -L INPUT -n --line-numbers
```

Sample outputs:

```
Chain INPUT (policy DROP)
num  target     prot opt source               destination
1    DROP       all  --  202.54.1.1           0.0.0.0/0
2    DROP       all  --  202.54.1.2           0.0.0.0/0
3    ACCEPT     all  --  0.0.0.0/0            0.0.0.0/0
     state NEW,ESTABLISHED
```

B.0.7 Save Firewall Rules

To save firewall rules under CentOS / RHEL / Fedora Linux, enter:

```
# service iptables save
```

In this example, drop an IP and save firewall rules:

```
# iptables -A INPUT -s 202.5.4.1 -j DROP
# service iptables save
```

For all other distros use the iptables-save command:

```
# iptables-save > /root/my.active.firewall.rules
# cat /root/my.active.firewall.rules
```

B.0.8 Restore Firewall Rules

To restore firewall rules form a file called /root/my.active.firewall.rules, enter:

```
# iptables-restore < /root/my.active.firewall.rules
```

To restore firewall rules under CentOS / RHEL / Fedora Linux, enter:

```
# service iptables restart
```

B.0.9 Set the Default Firewall Policies

To drop all traffic:

```
# iptables -P INPUT DROP
# iptables -P OUTPUT DROP
# iptables -P FORWARD DROP
# iptables -L -v -n
```

NOTE: You will not able to connect anywhere as all traffic is dropped

```
# ping teknixx.com
# wget http://www.kernel.org/pub/linux/kernel/v3.0/testing/linux-3.2-rc5.tar.bz2
```

B.0.10 Only Block Incoming Traffic

To drop all incoming / forwarded packets, but allow outgoing traffic, enter:

```
# iptables -P INPUT DROP
# iptables -P FORWARD DROP
# iptables -P OUTPUT ACCEPT
# iptables -A INPUT -m state --state RELATED,ESTABLISHED -j ACCEPT
# iptables -L -v -n
```

Now ping and wget should work

```
# ping teknixx.com
# wget http://www.kernel.org/pub/linux/kernel/v3.0/testing/linux-3.2-rc5.tar.bz2
```

B.0.11 Drop Private Network Address On Public Interface

IP spoofing is nothing but to stop the following IPv4 address ranges for private networks on your public interfaces. Packets with non-routable source addresses should be rejected using the following syntax:

```
# iptables -A INPUT -i eth1 -s 192.168.0.0/24 -j DROP
# iptables -A INPUT -i eth1 -s 10.0.0.0/8 -j DROP
```

IPv4 Address Ranges For Private Networks

- 10.0.0.0/8 -j (A)
- 172.16.0.0/12 (B)
- 192.168.0.0/16 (C)
- 224.0.0.0/4 (MULTICAST D)
- 240.0.0.0/5 (E)
- 127.0.0.0/8 (LOOPBACK)

B.0.12 Blocking an IP Address

To block an attackers ip address called 1.2.3.4, enter:

```
# iptables -A INPUT -s 1.2.3.4 -j DROP
# iptables -A INPUT -s 192.168.0.0/24 -j DROP
```

B.0.13 Block Incoming Port

To block all service requests on port 80, enter:

```
# iptables -A INPUT -p tcp --dport 80 -j DROP
# iptables -A INPUT -i eth1 -p tcp --dport 80 -j DROP
```

To block port 80 only for an ip address 1.2.3.4, enter:

```
# iptables -A INPUT -p tcp -s 1.2.3.4 --dport 80 -j DROP
# iptables -A INPUT -i eth1 -p tcp -s 192.168.1.0/24 --dport 80 -j DROP
```

B.0.14 Block Outgoing IP Address

To block outgoing traffic to a particular host or domain such as teknixx.com, enter:

```
# host -t a teknixx.com
```

Sample outputs: teknixx.com has address 75.126.153.206 Note down its ip address and type the following to block all outgoing traffic to 75.126.153.206:

```
# iptables -A OUTPUT -d 75.126.153.206 -j DROP
```

You can use a subnet as follows:

```
# iptables -A OUTPUT -d 192.168.1.0/24 -j DROP
# iptables -A OUTPUT -o eth1 -d 192.168.1.0/24 -j DROP
```

B.0.15 Block Domain

First, find out all ip address of facebook.com, enter:

```
# host -t a www.facebook.com
```

Sample outputs:

```
www.facebook.com has address 69.171.228.40
```

Find CIDR for 69.171.228.40, enter:

```
# whois 69.171.228.40 | grep CIDR
```

Sample outputs:

```
CIDR:           69.171.224.0/19
```

To prevent outgoing access to www.facebook.com, enter:

```
# iptables -A OUTPUT -p tcp -d 69.171.224.0/19 -j DROP
```

You can also use domain name, enter:

```
# iptables -A OUTPUT -p tcp -d www.facebook.com -j DROP
# iptables -A OUTPUT -p tcp -d facebook.com -j DROP
```

From the iptables man page:
specifying any name to be resolved with a remote query such as DNS (e.g., facebook.com is a really bad idea), a network IP address (with /mask), or a plain IP address

B.0.16 Log and Drop Packets

Type the following to log and block IP spoofing on public interface called eth1

```
# iptables -A INPUT -i eth1 -s 10.0.0.0/8 -j LOG --log-prefix "IP_SPOOF A: "
# iptables -A INPUT -i eth1 -s 10.0.0.0/8 -j DROP
```

By default everything is logged to /var/log/messages file.

```
# tail -f /var/log/messages
# grep --color 'IP SPOOF' /var/log/messages
```

B.0.17 Log and Drop Packets

The -m limit module can limit the number of log entries created per time. This is used to prevent flooding your log file. To log and drop spoofing per 5 minutes, in bursts of at most 7 entries .

```
# iptables -A INPUT -i eth1 -s 10.0.0.0/8 -m limit --limit 5/m --limit-burst 7 -j LOG --log-prefix "IP_SPOOF
# iptables -A INPUT -i eth1 -s 10.0.0.0/8 -j DROP
```

B.0.18 Drop or Accept Traffic From Mac Address

Use the following syntax:

```
# iptables -A INPUT -m mac --mac-source 00:0F:EA:91:04:08 -j DROP
## *only accept traffic for TCP port # 8080 from mac 00:0F:EA:91:04:07 * ##
# iptables -A INPUT -p tcp --destination-port 22 -m mac --mac-source 00:0F:EA:91:04:07 -j ACCEPT
```

B.0.19 Block or Allow Ping Request

Type the following command to block ICMP ping requests:

```
# iptables -A INPUT -p icmp --icmp-type echo-request -j DROP
# iptables -A INPUT -i eth1 -p icmp --icmp-type echo-request -j DROP
```

Ping responses can also be limited to certain networks or hosts:

```
# iptables -A INPUT -s 192.168.1.0/24 -p icmp --icmp-type echo-request -j ACCEPT
```

The following only accepts limited type of ICMP requests:

```
### ** assumed that default INPUT policy set to DROP ** ##############
iptables -A INPUT -p icmp --icmp-type echo-reply -j ACCEPT
iptables -A INPUT -p icmp --icmp-type destination-unreachable -j ACCEPT
iptables -A INPUT -p icmp --icmp-type time-exceeded -j ACCEPT
## ** all our server to respond to pings ** ##
iptables -A INPUT -p icmp --icmp-type echo-request -j ACCEPT
```

B.0.20 Open Range of Ports

Use the following syntax to open a range of ports:

```
iptables -A INPUT -m state --state NEW -m tcp -p tcp --dport 7000:7010 -j ACCEPT
```

B.0.21 Open Range of IP Addresses

Use the following syntax to open a range of IP address:

```
## only accept connection to tcp port 80 (Apache)
## if ip is between 192.168.1.100 and 192.168.1.200
iptables -A INPUT -p tcp --destination-port 80 -m iprange --src-range 192.168.1.100-192.168.1.20
## nat example ##
iptables -t nat -A POSTROUTING -j SNAT --to-source 192.168.1.20-192.168.1.25
```

B.0.22 Established Connections and Restaring The Firewall

When you restart the iptables service it will drop established connections as it unload modules from the system under RHEL / Fedora / CentOS Linux. Edit, /etc/sysconfig/iptables-config and set IPTABLES_MODULES_UNLOAD as follows:

```
IPTABLES_MODULES_UNLOAD = no
```

B.0.23 Help Iptables Flooding My Server Screen

Use the crit log level to send messages to a log file instead of console:

```
iptables -A INPUT -s 1.2.3.4 -p tcp --destination-port 80 -j LOG --log-level crit
```

B.0.24 Block or Open Common Ports

The following shows syntax for opening and closing common TCP and UDP ports:

```
Replace ACCEPT with DROP to block port:
## open port ssh tcp port 22 ##
iptables -A INPUT -m state --state NEW -m tcp -p tcp --dport 22 -j ACCEPT
iptables -A INPUT -s 192.168.1.0/24 -m state --state NEW -p tcp --dport 22 -j ACCEPT

## open cups (printing service) udp/tcp port 631 for LAN users ##
iptables -A INPUT -s 192.168.1.0/24 -p udp -m udp --dport 631 -j ACCEPT
iptables -A INPUT -s 192.168.1.0/24 -p tcp -m tcp --dport 631 -j ACCEPT
```

```
## allow time sync via NTP for lan users (open udp port 123) ##
iptables -A INPUT -s 192.168.1.0/24 -m state --state NEW -p udp --dport 123 -j ACCEPT

## open tcp port 25 (smtp) for all ##
iptables -A INPUT -m state --state NEW -p tcp --dport 25 -j ACCEPT

# open dns server ports for all ##
iptables -A INPUT -m state --state NEW -p udp --dport 53 -j ACCEPT
iptables -A INPUT -m state --state NEW -p tcp --dport 53 -j ACCEPT

## open http/https (Apache) server port to all ##
iptables -A INPUT -m state --state NEW -p tcp --dport 80 -j ACCEPT
iptables -A INPUT -m state --state NEW -p tcp --dport 443 -j ACCEPT

## open tcp port 110 (pop3) for all ##
iptables -A INPUT -m state --state NEW -p tcp --dport 110 -j ACCEPT

## open tcp port 143 (imap) for all ##
iptables -A INPUT -m state --state NEW -p tcp --dport 143 -j ACCEPT

## open access to Samba file server for lan users only ##
iptables -A INPUT -s 192.168.1.0/24 -m state --state NEW -p tcp --dport 137 -j ACCEPT
iptables -A INPUT -s 192.168.1.0/24 -m state --state NEW -p tcp --dport 138 -j ACCEPT
iptables -A INPUT -s 192.168.1.0/24 -m state --state NEW -p tcp --dport 139 -j ACCEPT
iptables -A INPUT -s 192.168.1.0/24 -m state --state NEW -p tcp --dport 445 -j ACCEPT

## open access to proxy server for lan users only ##
iptables -A INPUT -s 192.168.1.0/24 -m state --state NEW -p tcp --dport 3128 -j ACCEPT

## open access to mysql server for lan users only ##
iptables -I INPUT -p tcp --dport 3306 -j ACCEPT
```

B.0.25 Restrict the number of parallel connections

You can use connlimit module to put such restrictions. To allow 3 ssh connections per client host, enter:

```
# iptables -A INPUT -p tcp --syn --dport 22 -m connlimit --connlimit-above 3 -j REJECT
```

Set HTTP requests to 20:

```
# iptables -p tcp --syn --dport 80 -m connlimit --connlimit-above 20 --connlimit-mask 24 -j DROP
```

Where,

- connlimit-above 3 : Match if the number of existing connections is above 3.
- connlimit-mask 24 : Group hosts using the prefix length. For IPv4, this must be a number between (including) 0 and 32.

Appendix C

Makefile

— **makefile** —

```
# Just by typing 'make' will rebuild the book, extract the code, compile it,
# and run it.
all:
@ echo
@ echo make full ------- makes book, runs sha1 and ear, cleans
@ echo
@ echo make book ------- make the pdf
@ echo make code ------- runs the sha1 and ear stanzas
@ echo make ear -------- build and test ear.c
@ echo make sha1 ------- build and test sha1.c
@ echo make earandsha1 - build and test earandsha1.c
@ echo make vhdl ------- extract the VHDL for SHA1
@ echo
@ echo make makefile --- recreate this Makefile
@ echo make reference -- build the reference file for testing
@ echo make rfctest ---- run RFC 3174 SHA1 hash test code
@ echo make clean ------ remove files not checked into git
@ echo make tangle ----- make tangle for Literate Programming
@ echo make tgz -------- make a tgz file for shipping
@ echo

full: clean book sha1 ear earandsha1
@ make clean

makefile: tangle makefile.tex
@ ./tangle makefile.tex makefile >Makefile

code: sha1 ear earandsha1

# sha1sum reference.java = 4c963386437a56156a75a7f0da2302eee3ca881a
sha1: tangle Background.tex reference
```

```
@ ./tangle Background.tex sha1.c >sha1.c
@ gcc -o sha1 sha1.c
@ echo running sha1 reference.java refFileOut
@ rm -f refFileOut
@ ./sha1 reference.java refFileOut
@ wc reference.java
@ wc refFileOut

rfctest: tangle Background.tex
@ ./tangle Background.tex rfctest.c >rfctest.c
@ gcc -o rfctest rfctest.c
@ echo running rfctest
@ ./rfctest

ear: tangle FTPDetails.tex
@ ./tangle FTPDetails.tex ear.c >ear.c
@ gcc -o ear ear.c
@ sudo ./ear

earandsha1: tangle FTPDetails.tex
@ ./tangle FTPDetails.tex earandsha1.c >earandsha1.c
@ gcc -o earandsha1 earandsha1.c
@ sudo ./earandsha1

reference.java : reference.tex
@ ./tangle reference.tex reference.java >reference.java

reference: reference.tex
@ ./tangle reference.tex reference.java >reference.java

vhdl: tangle Sha1FPGA.tex
@ ./tangle Sha1FPGA.tex sha1.v >sha1.v

# typing 'make book' will create 'exfilt.pdf'
book: clean
@ latex exfilt.tex && makeindex exfilt.idx && latex exfilt.tex  \
         && dvipdfm exfilt.dvi
@ rm -f exfilt.log exfilt.out exfilt.aux exfilt.dvi exfilt.toc
@ rm -f *~

# the tangle program extracts code from latex sources
tangle: tangle.c
@ gcc -o tangle tangle.c

# typing 'make tar' will clean up everything and make a tar-gzip file
tgz: clean
@ ( cd .. ; tar -zcf exfilt.tgz exfilt )

# typing 'make clean' will remove any generated files
clean:
```

```
@ rm -f rfctest* sha1.v
@ rm -f ear.c ear
@ rm -f sha1.c sha1 refFileIn refFileout reference.java
@ rm -f tangle exfilt.idx exfilt.ild exfilt.ind exfilt.ilg
@ rm -f exfilt.log exfilt.out exfilt.aux exfilt.dvi exfilt.toc
@ rm -f *~
@ rm -f earandsha1 earandsha1.c log.txt
```

———-

Appendix D

The Tangle Program

— tangle.c —

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <sys/stat.h>
#include <sys/mman.h>
#include <fcntl.h>

// set this to 3 for further information
#define DEBUG 0

/* forward reference for the C compiler */
int getchunk(char *chunkname);

/* a memory mapped buffer copy of the file */
char *buffer;
int bufsize;

/* return the length of the next line */
int nextline(int i) {
  int j;
  if (i >= bufsize) return(-1);
  for (j=0; ((i+j < bufsize) && (buffer[i+j] != '\n')); j++);
  return(j);
}

/* output the line we need */
int printline(int i, int length) {
  int j;
  for (j=0; j<length; j++) { putchar(buffer[i+j]); }
  printf("\n");
}
```

```
/* handle begin{chunk}{chunkname}        */
/* is this chunk name we are looking for? &&
   does the line start with \begin{chunk}? &&
   is the next character a \{ &&
   is the last character after the chunkname a \}
*/
int foundchunk(int i, char *chunkname) {
  if ((strncmp(&buffer[i+14],chunkname,strlen(chunkname)) == 0) &&
      (strncmp(&buffer[i],"\\begin{chunk}",13) == 0) &&
      (buffer[i+13] == '{') &&
      (buffer[i+14+strlen(chunkname)] == '}')) {
    if (DEBUG==3) { printf("foundchunk(%s)\n",chunkname); }
    return(1);
  }
  return(0);
}

/* handle end{chunk}   */
/* is it really an end? */
int foundEnd(int i, char* chunkname) {
  if ((buffer[i] == '\\') &&
      (strncmp(&buffer[i+1],"end{chunk}",10) == 0)) {
    if (DEBUG==3) { printf("foundEnd(%s)\n",chunkname); }
    return(1);
  }
  return(0);
}

/* handle getchunk{chunkname} */
/* is this line a getchunk?    */
int foundGetchunk(int i, int linelen) {
  int len;
  if (strncmp(&buffer[i],"\\getchunk{",10) == 0) {
    for(len=0; ((len < linelen) && (buffer[i+len] != '}')); len++);
    return(len-10);
  }
  return(0);
}

/* Somebody did a getchunk and we need a copy of the name */
/* malloc string storage for a copy of the getchunk name  */
char *getChunkname(int k, int getlen) {
  char *result = (char *)malloc(getlen+1);
  strncpy(result,&buffer[k+10],getlen);
  result[getlen]='\0';
  return(result);
}

/* print lines in this chunk, possibly recursing into getchunk */
```

```
int printchunk(int i, int chunklinelen, char *chunkname) {
  int j;
  int k;
  int linelen;
  char *getname;
  int getlen = 0;
  if (DEBUG==3) { printf("===   \\start{%s}   ===\n",chunkname); }
  for (k=i+chunklinelen+1; ((linelen=nextline(k)) != -1); ) {
    if ((getlen=foundGetchunk(k,linelen)) > 0) {
       getname = getChunkname(k,getlen);
       getchunk(getname);
       free(getname);
       k=k+getlen+12l;
    } else {
      if ((linelen >= 11) && (foundEnd(k,chunkname) == 1)) {
      if (DEBUG==3) { printf("===   \\end{%s}   ===\n",chunkname); }
      return(k+12);
    } else {
      if (DEBUG==2) {
        printf("======== printchunk else %d %d\n",k,linelen);
      }
      printline(k,linelen);
      k=k+linelen+1;
    }
  }}
  if (DEBUG==2) {
     printf("=================\\out{%s} %d\n",chunkname,k);
  }
  return(k);
}

/* find the named chunk and call printchunk on it */
int getchunk(char *chunkname) {
  int i;
  int j;
  int linelen;
  int chunklen = strlen(chunkname);
  if (DEBUG==3) { printf("getchunk(%s)\n",chunkname); }
  for (i=0; ((linelen=nextline(i)) != -1); ) {
    if (DEBUG==2) {
      printf("----"); printline(i,linelen); printf("----\n");
    }
    if ((linelen >= chunklen+15) && (foundchunk(i,chunkname) == 1)) {
      if (DEBUG==2) {
         fprintf(stderr,"=================\\getchunk(%s)\n",chunkname);
      }
      i=printchunk(i,linelen,chunkname);
    } else {
      i=i+linelen+1;
    }
```

```
  }
  if (DEBUG==2) {
    fprintf(stderr,"=================getchunk returned=%d\n",i);
  }
  return(i);
}

/* memory map the input file into the global buffer and get the chunk */
int main(int argc, char *argv[]) {
  int fd;
  struct stat filestat;
  if ((argc == 1) || (argc > 3)) {
    perror("Usage: tangle filename chunkname");
    exit(-1);
  }
  fd = open(argv[1],O_RDONLY);
  if (fd == -1) {
    perror("Error opening file for reading");
    exit(-2);
  }
  if (fstat(fd,&filestat) < 0) {
    perror("Error getting input file size");
    exit(-3);
  }
  bufsize = (int)filestat.st_size;
  buffer = mmap(0,filestat.st_size,PROT_READ,MAP_SHARED,fd,0);
  if (buffer == MAP_FAILED) {
    close(fd);
    perror("Error reading the file");
    exit(-4);
  }
  if (argc == 2) {
    getchunk("*");
  } else {
    getchunk(argv[2]);
  }
  close(fd);
  return(0);
}
```

Appendix E

The reference file

E.1 The source text

This is the file we will use to check the prototype. It will be FTP'd from one machine to another.

— reference.java —

```
import java.io.IOException;
import java.util.ArrayList;
import java.util.Collection;
import java.util.List;
import org.apache.commons.configuration.ConfigurationException;
import org.apache.uima.UimaContext;
import org.apache.uima.analysis_component.JCasAnnotator_ImplBase;
import org.apache.uima.analysis_engine.AnalysisEngineProcessException;
import org.apache.uima.cas.FSIterator;
import org.apache.uima.jcas.JCas;
import org.apache.uima.jcas.cas.FSList;
import org.apache.uima.jcas.cas.StringList;
import org.apache.uima.resource.ResourceInitializationException;
import util.*;
import edu.cmu.lti.oaqa.bio.bioasq.services.GoPubMedService;
import edu.cmu.lti.oaqa.bio.bioasq.services.LinkedLifeDataServiceResponse;
import edu.cmu.lti.oaqa.bio.bioasq.services.OntologyServiceResponse;
import edu.cmu.lti.oaqa.bio.bioasq.services.PubMedSearchServiceResponse;
import edu.cmu.lti.oaqa.bio.bioasq.services.PubMedSearchServiceResponse.Document;
import edu.cmu.lti.oaqa.type.input.Question;
import edu.cmu.lti.oaqa.type.kb.Concept;
import edu.cmu.lti.oaqa.type.kb.Triple;

public class Annotator extends JCasAnnotator_ImplBase {
  static GoPubMedService service = null;

  @Override
```

```
public void initialize(UimaContext aContext) throws ResourceInitializationException {
  try {
    GoPubMedService service = new GoPubMedService("./project.properties");
  } catch (ConfigurationException e) {
    // TODO Auto-generated catch block
    e.printStackTrace();
  }
}

@Override
public void process(JCas aJCas) throws AnalysisEngineProcessException {
  // TODO Auto-generated method stub
  FSIterator it = aJCas.getAnnotationIndex(Question.type).iterator();
  // String Doc = aJCas.getDocumentText();
  Question questionTypeSys = null;
  if (it.hasNext()) {
    questionTypeSys = (Question) it.next();
  }
  String text = questionTypeSys.getText();
  Concept conceptTypeSys = null;
  // StringList conceptStringList = null;
  // FSList mentionList = null;
  List<String> conceptList = null;
  List<Double> confidenceList = null;
  edu.cmu.lti.oaqa.type.retrieval.Document documentTypeSys = null;
  // StringList documentStringList = null;
  Triple tripleTypeSys = null;
  try {
    OntologyServiceResponse.Result diseaseOntologyResult = service
            .findDiseaseOntologyEntitiesPaged(text, 0);
    conceptList = new ArrayList<String>();
    confidenceList = new ArrayList<Double>();
    conceptTypeSys = new Concept(aJCas);
    for (OntologyServiceResponse.Finding finding : diseaseOntologyResult.getFindings()) {
      conceptList.add(finding.getConcept().getUri());
      confidenceList.add(finding.getScore());
    }
    conceptTypeSys.setName("Disease Ontology");
    //conceptTypeSys.setUris(Utils.createStringList(aJCas, conceptList));
    //conceptTypeSys.setMentions(Utils.fromCollectionToFSList(aJCas, (Collection) confidenceLi
    conceptTypeSys.addToIndexes(aJCas);
    conceptList = new ArrayList<String>();
    confidenceList = new ArrayList<Double>();
    conceptTypeSys = new Concept(aJCas);
    OntologyServiceResponse.Result geneOntologyResult = service.findGeneOntologyEntitiesPaged(
            text, 0, 10);
    for (OntologyServiceResponse.Finding finding : geneOntologyResult.getFindings()) {
      conceptList.add(finding.getConcept().getUri());
      confidenceList.add(finding.getScore());
    }
```

```
conceptTypeSys.setName("Gene Ontology");
//conceptTypeSys.setUris(Utils.createStringList(aJCas, conceptList));
//conceptTypeSys.setMentions(Utils.fromCollectionToFSList(aJCas, (Collection) confidenceList));
conceptTypeSys.addToIndexes(aJCas);
conceptList = new ArrayList<String>();
confidenceList = new ArrayList<Double>();
conceptTypeSys = new Concept(aJCas);
OntologyServiceResponse.Result jochemResult = service.findJochemEntitiesPaged(text, 0);
for (OntologyServiceResponse.Finding finding : jochemResult.getFindings()) {
  conceptList.add(finding.getConcept().getUri());
  confidenceList.add(finding.getScore());
}
conceptTypeSys.setName("Jochem");
//conceptTypeSys.setUris(Utils.createStringList(aJCas, conceptList));
//conceptTypeSys.setMentions(Utils.fromCollectionToFSList(aJCas, (Collection) confidenceList));
conceptTypeSys.addToIndexes(aJCas);
conceptList = new ArrayList<String>();
confidenceList = new ArrayList<Double>();
conceptTypeSys = new Concept(aJCas);
OntologyServiceResponse.Result meshResult = service.findMeshEntitiesPaged(text, 0);
for (OntologyServiceResponse.Finding finding : meshResult.getFindings()) {
  conceptList.add(finding.getConcept().getUri());
  confidenceList.add(finding.getScore());
}
conceptTypeSys.setName("MeSH");
//conceptTypeSys.setUris(Utils.createStringList(aJCas, conceptList));
//conceptTypeSys.setMentions(Utils.fromCollectionToFSList(aJCas, (Collection) confidenceList));
conceptTypeSys.addToIndexes(aJCas);
conceptList = new ArrayList<String>();
confidenceList = new ArrayList<Double>();
conceptTypeSys = new Concept(aJCas);
OntologyServiceResponse.Result uniprotResult = service.findUniprotEntitiesPaged(text, 0);
for (OntologyServiceResponse.Finding finding : uniprotResult.getFindings()) {
  conceptList.add(finding.getConcept().getUri());
  confidenceList.add(finding.getScore());
}
conceptTypeSys.setName("UniProt");
//conceptTypeSys.setUris(Utils.createStringList(aJCas, conceptList));
//conceptTypeSys.setMentions(Utils.fromCollectionToFSList(aJCas, (Collection) confidenceList));
conceptTypeSys.addToIndexes(aJCas);
// Triples
LinkedLifeDataServiceResponse.Result linkedLifeDataResult = service
        .findLinkedLifeDataEntitiesPaged(text, 0);
// System.out.println("LinkedLifeData: " + linkedLifeDataResult.getEntities().size());
for (LinkedLifeDataServiceResponse.Entity entity : linkedLifeDataResult.getEntities()) {
  // System.out.println(" > " + entity.getEntity());
  for (LinkedLifeDataServiceResponse.Relation relation : entity.getRelations()) {
    tripleTypeSys = new Triple(aJCas);
    tripleTypeSys.setObject(relation.getObj());
    tripleTypeSys.setSubject(relation.getSubj());
```

```
          tripleTypeSys.setPredicate(relation.getPred());
          tripleTypeSys.addToIndexes(aJCas);
        }
      }
      PubMedSearchServiceResponse.Result pubmedResult = service.findPubMedCitations(text, 0);
      List<Document> docList = pubmedResult.getDocuments();
      // String[] pmids = new String[docList.size()];
      // int i = 0;
      for (Document doc : docList) {
        documentTypeSys = new edu.cmu.lti.oaqa.type.retrieval.Document(aJCas);
        documentTypeSys.setTitle("http://www.ncbi.nlm.nih.gov/pubmed/" + doc.getPmid());
        documentTypeSys.setDocId(doc.getPmid());
        documentTypeSys.addToIndexes(aJCas);
        // documentTypeSys.setDocId(doc);
        // pmids[i++] = "http://www.ncbi.nlm.nih.gov/pubmed/" + doc.getPmid();
        // System.out.println( pmids[i - 1]);
      }
    } catch (IOException e) {
      // TODO Auto-generated catch block
      e.printStackTrace();
    }
  }
}
```

E.2 The FTP packet frames

These are the bytes transmitted on the wire (captured by wireshark) during the FTP transfer.

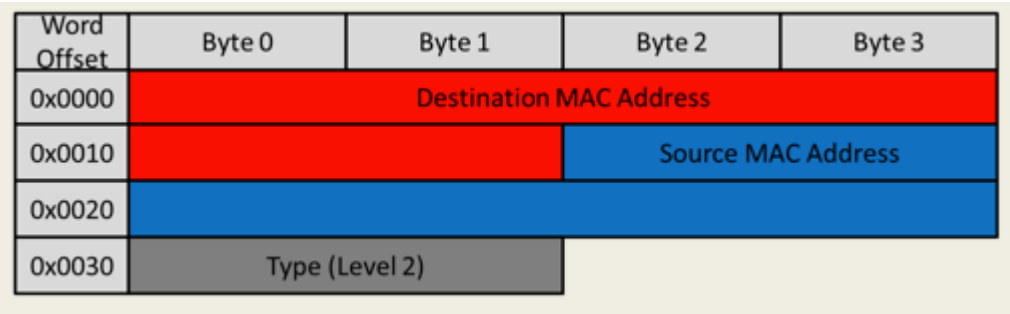


Figure E.1: The Level 1 Ethernet Header[37]

The Destination MAC address

```
0000 -- 0xd4, 0xbe, 0xd9, 0x50, 0xfa, 0xb2,             /* ...P..@< */
```

That is, D4:BE:D9:50:FA:B2

The Source MAC address

```
0000 --                                   0x40, 0x3c, /* ...P..@< */
0008 -- 0xfc, 0x01, 0x04, 0x85,                       /* ......E. */
```

That is, 40:3C:FC:01:04:85

Type

```
0008 --                         0x08, 0x00,           /* ......E. */
```

If the type field of the Ethernet header contains 0x0800 (which this does) there will be a second nested level. The contents of this level are described by the IP header.

Version (4 bits)

```
0008 --                                   0x4 ,       /* ......E. */
```

The Version is 4, which signals IPv4

Internet Header Length (4 bits)

```
0008 --                                     0x 5,     /* ......E. */
```

The Internet Header Length is 5, which means 5x32 = 160 bits =20 bytes

Type of Service (1 byte)

```
0008 --                                         0x08, /* ......E. */
```

This field is actually 2 fields, a 6-bit Differentiated Servies Code Point and and Explicit Congestion Notification (2 bit). [41]

Total Length (2 bytes)

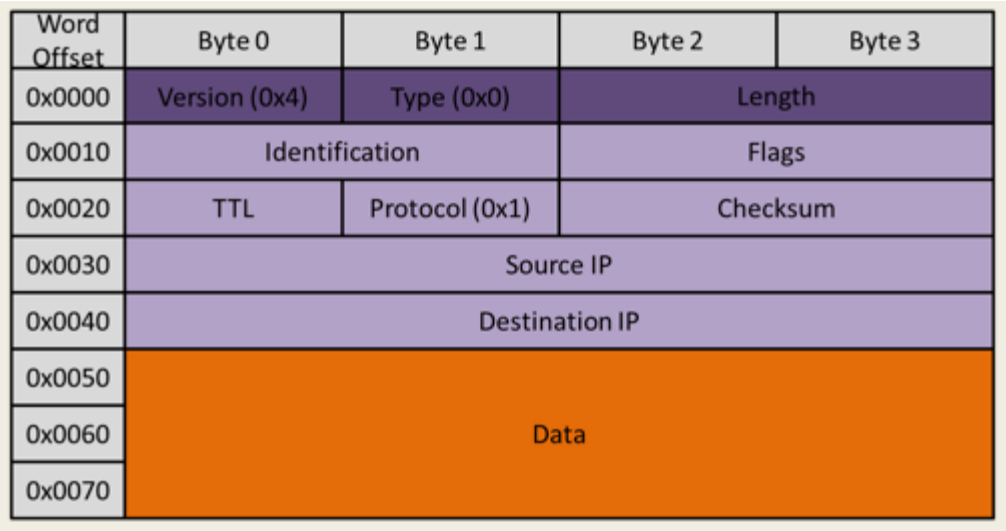


Figure E.2: The Level 2 IP Ethernet Header[37]

```
0010 -- 0x05, 0xdc,                                    /* ..rD@.@. */
```

Hex 0x5DC = 1500

Identification (2 bytes)

```
0010 --           0x72, 0x44,                          /* ..rD@.@. */
```

The identiication field is primarily used for uniquely identifying the group of fragments of a single IP datagram. [41]

Flags (3 bits)

```
0010 --                      0x4                       /* ..rD@.@. */
0010 --                      0x 0, 0x00                /* ..rD@.@. */
```

This 3-bit field is used to control or identify fragments. This has the Don't Fragment (DF) bit set.[41]

Fragmentation Offset (13 bits)

```
0010 --                      0x 0, 0x00                /* ..rD@.@. */
```

The packet is not fragmented so there is no offset.

Time to Live (1 byte)

```
0010 --                                  0x40          /* ..rD@.@. */
```

Supposed to be a number of seconds but is usually a hop count.

Protocol (1 bytes) [43]

```
0010 --                                        0x06, /* ..rD@.@. */
```

The 6 identifies this as a TCP packet. Note the FTP is a TCP-based protocol.

Header Checksum (2 bytes)

```
0018 -- 0x3f, 0x7c, 0xc0, 0xa8                          /* ?|..... */
```

0x3F7CC0A8 = 1065140392

RFC 1071 defines the checksum calculation:

The checksum field is the 16-bit one's complement of the one's complement sum of all 16-bit words in the header. For purposes of computing the checksum, the value of the checksum field is zero.

For example, consider

```
Hex 450000304422400080060000 8c7c19ac ae241e2b
```

(20 bytes IP header), using a machine which uses standard two's complement arithmetic:

1. 4500 + 0030 + 4422 + 4000 + 8006 + 0000 + 8c7c + 19ac + ae24 + 1e2b = 0002BBCF (32-bit sum)
2. 0002 + BBCF = BBD1 = 1011101111010001 (1's complement 16-bit sum, formed by "end around carry" of 32-bit 2's complement sum)
3. BBD1 = 0100010000101110 = 442E (1's complement of 1's complement 16-bit sum)

To validate a header's checksum the same algorithm may be used - the checksum of a header which contains a correct checksum field is a word containing all zeros (value 0):

```
2BBCF + 442E = 2FFFD. 2 + FFFD = FFFF. the 1's complement of FFFF = 0.
```

The Source Address (4 bytes)

```
0018 --                         0x01, 0x02, 0xc0, 0xa8, /* ?|..... */
```

This is 192.168.1.2

The Destination Address (4 bytes)

```
0020 -- 0x01, 0x01, 0x00, 0x14,                         /* .....u.. */
```

This appears to be 0.20.1.1 (which is nonsense)

These bytes still need to be explained:

```
0020 --                         0xdf, 0x75, 0xe1, 0x89, /* .....u.. */
0028 -- 0xc7, 0x42, 0x28, 0x0a, 0x7e, 0xea, 0x80, 0x10, /* .B(.~... */
0030 -- 0x01, 0xc9, 0x8b, 0x61, 0x00, 0x00, 0x01, 0x01, /* ...a.... */
```

The **Data** packet (offset x42)

```
  i     m     p     o     r     t
0042 -- 0x69, 0x6d, 0x70, 0x6f, 0x72, 0x74, /* import */
```

The data packet length is 1514-66=1448 bytes (x42=66, the header length).

— **referenceFrames** —

```
/* Frame (1514 bytes) */
static const unsigned char pkt11[1514] = {
0xd4, 0xbe, 0xd9, 0x50, 0xfa, 0xb2, 0x40, 0x3c, /* ...P..@< */
0xfc, 0x01, 0x04, 0x85, 0x08, 0x00, 0x45, 0x08, /* ......E. */
0x05, 0xdc, 0x72, 0x44, 0x40, 0x00, 0x40, 0x06, /* ..rD@.@. */
0x3f, 0x7c, 0xc0, 0xa8, 0x01, 0x02, 0xc0, 0xa8, /* ?|...... */
0x01, 0x01, 0x00, 0x14, 0xdf, 0x75, 0xe1, 0x89, /* .....u.. */
0xc7, 0x42, 0x28, 0x0a, 0x7e, 0xea, 0x80, 0x10, /* .B(.~... */
0x01, 0xc9, 0x8b, 0x61, 0x00, 0x00, 0x01, 0x01, /* ...a.... */
0x08, 0x0a, 0x00, 0xf8, 0xb5, 0x03, 0x00, 0x07, /* ........ */
0x27, 0x99, 0x69, 0x6d, 0x70, 0x6f, 0x72, 0x74, /* '.import */
0x20, 0x6a, 0x61, 0x76, 0x61, 0x2e, 0x69, 0x6f, /*  java.io */
0x2e, 0x49, 0x4f, 0x45, 0x78, 0x63, 0x65, 0x70, /* .IOExcep */
0x74, 0x69, 0x6f, 0x6e, 0x3b, 0x0a, 0x69, 0x6d, /* tion;.im */
0x70, 0x6f, 0x72, 0x74, 0x20, 0x6a, 0x61, 0x76, /* port jav */
0x61, 0x2e, 0x75, 0x74, 0x69, 0x6c, 0x2e, 0x41, /* a.util.A */
0x72, 0x72, 0x61, 0x79, 0x4c, 0x69, 0x73, 0x74, /* rrayList */
0x3b, 0x0a, 0x69, 0x6d, 0x70, 0x6f, 0x72, 0x74, /* ;.import */
0x20, 0x6a, 0x61, 0x76, 0x61, 0x2e, 0x75, 0x74, /*  java.ut */
0x69, 0x6c, 0x2e, 0x43, 0x6f, 0x6c, 0x6c, 0x65, /* il.Colle */
0x63, 0x74, 0x69, 0x6f, 0x6e, 0x3b, 0x0a, 0x69, /* ction;.i */
0x6d, 0x70, 0x6f, 0x72, 0x74, 0x20, 0x6a, 0x61, /* mport ja */
0x76, 0x61, 0x2e, 0x75, 0x74, 0x69, 0x6c, 0x2e, /* va.util. */
0x4c, 0x69, 0x73, 0x74, 0x3b, 0x0a, 0x69, 0x6d, /* List;.im */
0x70, 0x6f, 0x72, 0x74, 0x20, 0x6f, 0x72, 0x67, /* port org */
0x2e, 0x61, 0x70, 0x61, 0x63, 0x68, 0x65, 0x2e, /* .apache. */
0x63, 0x6f, 0x6d, 0x6d, 0x6f, 0x6e, 0x73, 0x2e, /* commons. */
0x63, 0x6f, 0x6e, 0x66, 0x69, 0x67, 0x75, 0x72, /* configur */
0x61, 0x74, 0x69, 0x6f, 0x6e, 0x2e, 0x43, 0x6f, /* ation.Co */
0x6e, 0x66, 0x69, 0x67, 0x75, 0x72, 0x61, 0x74, /* nfigurat */
0x69, 0x6f, 0x6e, 0x45, 0x78, 0x63, 0x65, 0x70, /* ionExcep */
0x74, 0x69, 0x6f, 0x6e, 0x3b, 0x0a, 0x69, 0x6d, /* tion;.im */
0x70, 0x6f, 0x72, 0x74, 0x20, 0x6f, 0x72, 0x67, /* port org */
0x2e, 0x61, 0x70, 0x61, 0x63, 0x68, 0x65, 0x2e, /* .apache. */
0x75, 0x69, 0x6d, 0x61, 0x2e, 0x55, 0x69, 0x6d, /* uima.Uim */
0x61, 0x43, 0x6f, 0x6e, 0x74, 0x65, 0x78, 0x74, /* aContext */
0x3b, 0x0a, 0x69, 0x6d, 0x70, 0x6f, 0x72, 0x74, /* ;.import */
0x20, 0x6f, 0x72, 0x67, 0x2e, 0x61, 0x70, 0x61, /*  org.apa */
0x63, 0x68, 0x65, 0x2e, 0x75, 0x69, 0x6d, 0x61, /* che.uima */
0x2e, 0x61, 0x6e, 0x61, 0x6c, 0x79, 0x73, 0x69, /* .analysi */
0x73, 0x5f, 0x63, 0x6f, 0x6d, 0x70, 0x6f, 0x6e, /* s_compon */
0x65, 0x6e, 0x74, 0x2e, 0x4a, 0x43, 0x61, 0x73, /* ent.JCas */
0x41, 0x6e, 0x6e, 0x6f, 0x74, 0x61, 0x74, 0x6f, /* Annotato */
0x72, 0x5f, 0x49, 0x6d, 0x70, 0x6c, 0x42, 0x61, /* r_ImplBa */
0x73, 0x65, 0x3b, 0x0a, 0x69, 0x6d, 0x70, 0x6f, /* se;.impo */
0x72, 0x74, 0x20, 0x6f, 0x72, 0x67, 0x2e, 0x61, /* rt org.a */
0x70, 0x61, 0x63, 0x68, 0x65, 0x2e, 0x75, 0x69, /* pache.ui */
0x6d, 0x61, 0x2e, 0x61, 0x6e, 0x61, 0x6c, 0x79, /* ma.analy */
0x73, 0x69, 0x73, 0x5f, 0x65, 0x6e, 0x67, 0x69, /* sis_engi */
0x6e, 0x65, 0x2e, 0x41, 0x6e, 0x61, 0x6c, 0x79, /* ne.Analy */
```

```
0x73, 0x69, 0x73, 0x45, 0x6e, 0x67, 0x69, 0x6e, /* sisEngin */
0x65, 0x50, 0x72, 0x6f, 0x63, 0x65, 0x73, 0x73, /* eProcess */
0x45, 0x78, 0x63, 0x65, 0x70, 0x74, 0x69, 0x6f, /* Exceptio */
0x6e, 0x3b, 0x0a, 0x69, 0x6d, 0x70, 0x6f, 0x72, /* n;.impor */
0x74, 0x20, 0x6f, 0x72, 0x67, 0x2e, 0x61, 0x70, /* t org.ap */
0x61, 0x63, 0x68, 0x65, 0x2e, 0x75, 0x69, 0x6d, /* ache.uim */
0x61, 0x2e, 0x63, 0x61, 0x73, 0x2e, 0x46, 0x53, /* a.cas.FS */
0x49, 0x74, 0x65, 0x72, 0x61, 0x74, 0x6f, 0x72, /* Iterator */
0x3b, 0x0a, 0x69, 0x6d, 0x70, 0x6f, 0x72, 0x74, /* ;.import */
0x20, 0x6f, 0x72, 0x67, 0x2e, 0x61, 0x70, 0x61, /*  org.apa */
0x63, 0x68, 0x65, 0x2e, 0x75, 0x69, 0x6d, 0x61, /* che.uima */
0x2e, 0x6a, 0x63, 0x61, 0x73, 0x2e, 0x4a, 0x43, /* .jcas.JC */
0x61, 0x73, 0x3b, 0x0a, 0x69, 0x6d, 0x70, 0x6f, /* as;.impo */
0x72, 0x74, 0x20, 0x6f, 0x72, 0x67, 0x2e, 0x61, /* rt org.a */
0x70, 0x61, 0x63, 0x68, 0x65, 0x2e, 0x75, 0x69, /* pache.ui */
0x6d, 0x61, 0x2e, 0x6a, 0x63, 0x61, 0x73, 0x2e, /* ma.jcas. */
0x63, 0x61, 0x73, 0x2e, 0x46, 0x53, 0x4c, 0x69, /* cas.FSLi */
0x73, 0x74, 0x3b, 0x0a, 0x69, 0x6d, 0x70, 0x6f, /* st;.impo */
0x72, 0x74, 0x20, 0x6f, 0x72, 0x67, 0x2e, 0x61, /* rt org.a */
0x70, 0x61, 0x63, 0x68, 0x65, 0x2e, 0x75, 0x69, /* pache.ui */
0x6d, 0x61, 0x2e, 0x6a, 0x63, 0x61, 0x73, 0x2e, /* ma.jcas. */
0x63, 0x61, 0x73, 0x2e, 0x53, 0x74, 0x72, 0x69, /* cas.Stri */
0x6e, 0x67, 0x4c, 0x69, 0x73, 0x74, 0x3b, 0x0a, /* ngList;. */
0x69, 0x6d, 0x70, 0x6f, 0x72, 0x74, 0x20, 0x6f, /* import o */
0x72, 0x67, 0x2e, 0x61, 0x70, 0x61, 0x63, 0x68, /* rg.apach */
0x65, 0x2e, 0x75, 0x69, 0x6d, 0x61, 0x2e, 0x72, /* e.uima.r */
0x65, 0x73, 0x6f, 0x75, 0x72, 0x63, 0x65, 0x2e, /* esource. */
0x52, 0x65, 0x73, 0x6f, 0x75, 0x72, 0x63, 0x65, /* Resource */
0x49, 0x6e, 0x69, 0x74, 0x69, 0x61, 0x6c, 0x69, /* Initiali */
0x7a, 0x61, 0x74, 0x69, 0x6f, 0x6e, 0x45, 0x78, /* zationEx */
0x63, 0x65, 0x70, 0x74, 0x69, 0x6f, 0x6e, 0x3b, /* ception; */
0x0a, 0x69, 0x6d, 0x70, 0x6f, 0x72, 0x74, 0x20, /* .import  */
0x75, 0x74, 0x69, 0x6c, 0x2e, 0x2a, 0x3b, 0x0a, /* util.*;. */
0x69, 0x6d, 0x70, 0x6f, 0x72, 0x74, 0x20, 0x65, /* import e */
0x64, 0x75, 0x2e, 0x63, 0x6d, 0x75, 0x2e, 0x6c, /* du.cmu.l */
0x74, 0x69, 0x2e, 0x6f, 0x61, 0x71, 0x61, 0x2e, /* ti.oaqa. */
0x62, 0x69, 0x6f, 0x2e, 0x62, 0x69, 0x6f, 0x61, /* bio.bioa */
0x73, 0x71, 0x2e, 0x73, 0x65, 0x72, 0x76, 0x69, /* sq.servi */
0x63, 0x65, 0x73, 0x2e, 0x47, 0x6f, 0x50, 0x75, /* ces.GoPu */
0x62, 0x4d, 0x65, 0x64, 0x53, 0x65, 0x72, 0x76, /* bMedServ */
0x69, 0x63, 0x65, 0x3b, 0x0a, 0x69, 0x6d, 0x70, /* ice;.imp */
0x6f, 0x72, 0x74, 0x20, 0x65, 0x64, 0x75, 0x2e, /* ort edu. */
0x63, 0x6d, 0x75, 0x2e, 0x6c, 0x74, 0x69, 0x2e, /* cmu.lti. */
0x6f, 0x61, 0x71, 0x61, 0x2e, 0x62, 0x69, 0x6f, /* oaqa.bio */
0x2e, 0x62, 0x69, 0x6f, 0x61, 0x73, 0x71, 0x2e, /* .bioasq. */
0x73, 0x65, 0x72, 0x76, 0x69, 0x63, 0x65, 0x73, /* services */
0x2e, 0x4c, 0x69, 0x6e, 0x6b, 0x65, 0x64, 0x4c, /* .LinkedL */
0x69, 0x66, 0x65, 0x44, 0x61, 0x74, 0x61, 0x53, /* ifeDataS */
0x65, 0x72, 0x76, 0x69, 0x63, 0x65, 0x52, 0x65, /* erviceRe */
0x73, 0x70, 0x6f, 0x6e, 0x73, 0x65, 0x3b, 0x0a, /* sponse;. */
```

```
0x69, 0x6d, 0x70, 0x6f, 0x72, 0x74, 0x20, 0x65, /* import e */
0x64, 0x75, 0x2e, 0x63, 0x6d, 0x75, 0x2e, 0x6c, /* du.cmu.l */
0x74, 0x69, 0x2e, 0x6f, 0x61, 0x71, 0x61, 0x2e, /* ti.oaqa. */
0x62, 0x69, 0x6f, 0x2e, 0x62, 0x69, 0x6f, 0x61, /* bio.bioa */
0x73, 0x71, 0x2e, 0x73, 0x65, 0x72, 0x76, 0x69, /* sq.servi */
0x63, 0x65, 0x73, 0x2e, 0x4f, 0x6e, 0x74, 0x6f, /* ces.Onto */
0x6c, 0x6f, 0x67, 0x79, 0x53, 0x65, 0x72, 0x76, /* logyServ */
0x69, 0x63, 0x65, 0x52, 0x65, 0x73, 0x70, 0x6f, /* iceRespo */
0x6e, 0x73, 0x65, 0x3b, 0x0a, 0x69, 0x6d, 0x70, /* nse;.imp */
0x6f, 0x72, 0x74, 0x20, 0x65, 0x64, 0x75, 0x2e, /* ort edu. */
0x63, 0x6d, 0x75, 0x2e, 0x6c, 0x74, 0x69, 0x2e, /* cmu.lti. */
0x6f, 0x61, 0x71, 0x61, 0x2e, 0x62, 0x69, 0x6f, /* oaqa.bio */
0x2e, 0x62, 0x69, 0x6f, 0x61, 0x73, 0x71, 0x2e, /* .bioasq. */
0x73, 0x65, 0x72, 0x76, 0x69, 0x63, 0x65, 0x73, /* services */
0x2e, 0x50, 0x75, 0x62, 0x4d, 0x65, 0x64, 0x53, /* .PubMedS */
0x65, 0x61, 0x72, 0x63, 0x68, 0x53, 0x65, 0x72, /* earchSer */
0x76, 0x69, 0x63, 0x65, 0x52, 0x65, 0x73, 0x70, /* viceResp */
0x6f, 0x6e, 0x73, 0x65, 0x3b, 0x0a, 0x69, 0x6d, /* onse;.im */
0x70, 0x6f, 0x72, 0x74, 0x20, 0x65, 0x64, 0x75, /* port edu */
0x2e, 0x63, 0x6d, 0x75, 0x2e, 0x6c, 0x74, 0x69, /* .cmu.lti */
0x2e, 0x6f, 0x61, 0x71, 0x61, 0x2e, 0x62, 0x69, /* .oaqa.bi */
0x6f, 0x2e, 0x62, 0x69, 0x6f, 0x61, 0x73, 0x71, /* o.bioasq */
0x2e, 0x73, 0x65, 0x72, 0x76, 0x69, 0x63, 0x65, /* .service */
0x73, 0x2e, 0x50, 0x75, 0x62, 0x4d, 0x65, 0x64, /* s.PubMed */
0x53, 0x65, 0x61, 0x72, 0x63, 0x68, 0x53, 0x65, /* SearchSe */
0x72, 0x76, 0x69, 0x63, 0x65, 0x52, 0x65, 0x73, /* rviceRes */
0x70, 0x6f, 0x6e, 0x73, 0x65, 0x2e, 0x44, 0x6f, /* ponse.Do */
0x63, 0x75, 0x6d, 0x65, 0x6e, 0x74, 0x3b, 0x0a, /* cument;. */
0x69, 0x6d, 0x70, 0x6f, 0x72, 0x74, 0x20, 0x65, /* import e */
0x64, 0x75, 0x2e, 0x63, 0x6d, 0x75, 0x2e, 0x6c, /* du.cmu.l */
0x74, 0x69, 0x2e, 0x6f, 0x61, 0x71, 0x61, 0x2e, /* ti.oaqa. */
0x74, 0x79, 0x70, 0x65, 0x2e, 0x69, 0x6e, 0x70, /* type.inp */
0x75, 0x74, 0x2e, 0x51, 0x75, 0x65, 0x73, 0x74, /* ut.Quest */
0x69, 0x6f, 0x6e, 0x3b, 0x0a, 0x69, 0x6d, 0x70, /* ion;.imp */
0x6f, 0x72, 0x74, 0x20, 0x65, 0x64, 0x75, 0x2e, /* ort edu. */
0x63, 0x6d, 0x75, 0x2e, 0x6c, 0x74, 0x69, 0x2e, /* cmu.lti. */
0x6f, 0x61, 0x71, 0x61, 0x2e, 0x74, 0x79, 0x70, /* oaqa.typ */
0x65, 0x2e, 0x6b, 0x62, 0x2e, 0x43, 0x6f, 0x6e, /* e.kb.Con */
0x63, 0x65, 0x70, 0x74, 0x3b, 0x0a, 0x69, 0x6d, /* cept;.im */
0x70, 0x6f, 0x72, 0x74, 0x20, 0x65, 0x64, 0x75, /* port edu */
0x2e, 0x63, 0x6d, 0x75, 0x2e, 0x6c, 0x74, 0x69, /* .cmu.lti */
0x2e, 0x6f, 0x61, 0x71, 0x61, 0x2e, 0x74, 0x79, /* .oaqa.ty */
0x70, 0x65, 0x2e, 0x6b, 0x62, 0x2e, 0x54, 0x72, /* pe.kb.Tr */
0x69, 0x70, 0x6c, 0x65, 0x3b, 0x0a, 0x0a, 0x70, /* iple;..p */
0x75, 0x62, 0x6c, 0x69, 0x63, 0x20, 0x63, 0x6c, /* ublic cl */
0x61, 0x73, 0x73, 0x20, 0x41, 0x6e, 0x6e, 0x6f, /* ass Anno */
0x74, 0x61, 0x74, 0x6f, 0x72, 0x20, 0x65, 0x78, /* tator ex */
0x74, 0x65, 0x6e, 0x64, 0x73, 0x20, 0x4a, 0x43, /* tends JC */
0x61, 0x73, 0x41, 0x6e, 0x6e, 0x6f, 0x74, 0x61, /* asAnnota */
0x74, 0x6f, 0x72, 0x5f, 0x49, 0x6d, 0x70, 0x6c, /* tor_Impl */
```

```
0x42, 0x61, 0x73, 0x65, 0x20, 0x7b, 0x0a, 0x20, /* Base {.  */
0x20, 0x73, 0x74, 0x61, 0x74, 0x69, 0x63, 0x20, /*  static  */
0x47, 0x6f, 0x50, 0x75, 0x62, 0x4d, 0x65, 0x64, /* GoPubMed */
0x53, 0x65, 0x72, 0x76, 0x69, 0x63, 0x65, 0x20, /* Service  */
0x73, 0x65, 0x72, 0x76, 0x69, 0x63, 0x65, 0x20, /* service  */
0x3d, 0x20, 0x6e, 0x75, 0x6c, 0x6c, 0x3b, 0x0a, /* = null;. */
0x0a, 0x20, 0x20, 0x40, 0x4f, 0x76, 0x65, 0x72, /* .  @Over */
0x72, 0x69, 0x64, 0x65, 0x0a, 0x20, 0x20, 0x70, /* ride.  p */
0x75, 0x62, 0x6c, 0x69, 0x63, 0x20, 0x76, 0x6f, /* ublic vo */
0x69, 0x64, 0x20, 0x69, 0x6e, 0x69, 0x74, 0x69, /* id initi */
0x61, 0x6c, 0x69, 0x7a, 0x65, 0x28, 0x55, 0x69, /* alize(Ui */
0x6d, 0x61, 0x43, 0x6f, 0x6e, 0x74, 0x65, 0x78, /* maContex */
0x74, 0x20, 0x61, 0x43, 0x6f, 0x6e, 0x74, 0x65, /* t aConte */
0x78, 0x74, 0x29, 0x20, 0x74, 0x68, 0x72, 0x6f, /* xt) thro */
0x77, 0x73, 0x20, 0x52, 0x65, 0x73, 0x6f, 0x75, /* ws Resou */
0x72, 0x63, 0x65, 0x49, 0x6e, 0x69, 0x74, 0x69, /* rceIniti */
0x61, 0x6c, 0x69, 0x7a, 0x61, 0x74, 0x69, 0x6f, /* alizatio */
0x6e, 0x45, 0x78, 0x63, 0x65, 0x70, 0x74, 0x69, /* nExcepti */
0x6f, 0x6e, 0x20, 0x7b, 0x0a, 0x20, 0x20, 0x20, /* on {.    */
0x20, 0x74, 0x72, 0x79, 0x20, 0x7b, 0x0a, 0x20, /*  try {.  */
0x20, 0x20, 0x20, 0x20, 0x20, 0x47, 0x6f, 0x50, /*      GoP */
0x75, 0x62, 0x4d, 0x65, 0x64, 0x53, 0x65, 0x72, /* ubMedSer */
0x76, 0x69, 0x63, 0x65, 0x20, 0x73, 0x65, 0x72, /* vice ser */
0x76, 0x69, 0x63, 0x65, 0x20, 0x3d, 0x20, 0x6e, /* vice = n */
0x65, 0x77, 0x20, 0x47, 0x6f, 0x50, 0x75, 0x62, /* ew GoPub */
0x4d, 0x65, 0x64, 0x53, 0x65, 0x72, 0x76, 0x69, /* MedServi */
0x63, 0x65, 0x28, 0x22, 0x2e, 0x2f, 0x70, 0x72, /* ce("./pr */
0x6f, 0x6a, 0x65, 0x63, 0x74, 0x2e, 0x70, 0x72, /* oject.pr */
0x6f, 0x70, 0x65, 0x72, 0x74, 0x69, 0x65, 0x73, /* operties */
0x22, 0x29, 0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, /* ");.     */
0x7d, 0x20, 0x63, 0x61, 0x74, 0x63, 0x68, 0x20, /* } catch  */
0x28, 0x43, 0x6f, 0x6e, 0x66, 0x69, 0x67, 0x75, /* (Configu */
0x72, 0x61, 0x74, 0x69, 0x6f, 0x6e, 0x45, 0x78, /* rationEx */
0x63, 0x65, 0x70, 0x74, 0x69, 0x6f, 0x6e, 0x20, /* ception  */
0x65, 0x29, 0x20, 0x7b, 0x0a, 0x20, 0x20, 0x20, /* e) {.    */
0x20, 0x20, 0x20, 0x2f, 0x2f, 0x20, 0x54, 0x4f, /*    // TO */
0x44, 0x4f, 0x20, 0x41, 0x75, 0x74, 0x6f, 0x2d, /* DO Auto- */
0x67, 0x65, 0x6e, 0x65, 0x72, 0x61, 0x74, 0x65, /* generate */
0x64, 0x20, 0x63, 0x61, 0x74, 0x63, 0x68, 0x20, /* d catch  */
0x62, 0x6c, 0x6f, 0x63, 0x6b, 0x0a, 0x20, 0x20, /* block.   */
0x20, 0x20, 0x20, 0x20, 0x65, 0x2e, 0x70, 0x72, /*     e.pr */
0x69, 0x6e                                      /* in */
};

/* Frame (1514 bytes) */
static const unsigned char pkt13[1514] = {
0xd4, 0xbe, 0xd9, 0x50, 0xfa, 0xb2, 0x40, 0x3c, /* ...P..@< */
0xfc, 0x01, 0x04, 0x85, 0x08, 0x00, 0x45, 0x08, /* ......E. */
0x05, 0xdc, 0x72, 0x45, 0x40, 0x00, 0x40, 0x06, /* ..rE@.@. */
0x3f, 0x7b, 0xc0, 0xa8, 0x01, 0x02, 0xc0, 0xa8, /* ?{...... */
```

```
0x01, 0x01, 0x00, 0x14, 0xdf, 0x75, 0xe1, 0x89, /* .....u.. */
0xcc, 0xea, 0x28, 0x0a, 0x7e, 0xea, 0x80, 0x10, /* ..(.~... */
0x01, 0xc9, 0x0a, 0x8a, 0x00, 0x00, 0x01, 0x01, /* ........ */
0x08, 0x0a, 0x00, 0xf8, 0xb5, 0x03, 0x00, 0x07, /* ........ */
0x27, 0x99, 0x74, 0x53, 0x74, 0x61, 0x63, 0x6b, /* '.tStack */
0x54, 0x72, 0x61, 0x63, 0x65, 0x28, 0x29, 0x3b, /* Trace(); */
0x0a, 0x20, 0x20, 0x20, 0x20, 0x7d, 0x0a, 0x20, /* .    }.  */
0x20, 0x7d, 0x0a, 0x0a, 0x20, 0x20, 0x40, 0x4f, /*  }..  @O */
0x76, 0x65, 0x72, 0x72, 0x69, 0x64, 0x65, 0x0a, /* verride. */
0x20, 0x20, 0x70, 0x75, 0x62, 0x6c, 0x69, 0x63, /*   public */
0x20, 0x76, 0x6f, 0x69, 0x64, 0x20, 0x70, 0x72, /*  void pr */
0x6f, 0x63, 0x65, 0x73, 0x73, 0x28, 0x4a, 0x43, /* ocess(JC */
0x61, 0x73, 0x20, 0x61, 0x4a, 0x43, 0x61, 0x73, /* as aJCas */
0x29, 0x20, 0x74, 0x68, 0x72, 0x6f, 0x77, 0x73, /* ) throws */
0x20, 0x41, 0x6e, 0x61, 0x6c, 0x79, 0x73, 0x69, /*  Analysi */
0x73, 0x45, 0x6e, 0x67, 0x69, 0x6e, 0x65, 0x50, /* sEngineP */
0x72, 0x6f, 0x63, 0x65, 0x73, 0x73, 0x45, 0x78, /* rocessEx */
0x63, 0x65, 0x70, 0x74, 0x69, 0x6f, 0x6e, 0x20, /* ception  */
0x7b, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x2f, 0x2f, /* {.    // */
0x20, 0x54, 0x4f, 0x44, 0x4f, 0x20, 0x41, 0x75, /*  TODO Au */
0x74, 0x6f, 0x2d, 0x67, 0x65, 0x6e, 0x65, 0x72, /* to-gener */
0x61, 0x74, 0x65, 0x64, 0x20, 0x6d, 0x65, 0x74, /* ated met */
0x68, 0x6f, 0x64, 0x20, 0x73, 0x74, 0x75, 0x62, /* hod stub */
0x0a, 0x20, 0x20, 0x20, 0x20, 0x46, 0x53, 0x49, /* .    FSI */
0x74, 0x65, 0x72, 0x61, 0x74, 0x6f, 0x72, 0x20, /* terator  */
0x69, 0x74, 0x20, 0x3d, 0x20, 0x61, 0x4a, 0x43, /* it = aJC */
0x61, 0x73, 0x2e, 0x67, 0x65, 0x74, 0x41, 0x6e, /* as.getAn */
0x6e, 0x6f, 0x74, 0x61, 0x74, 0x69, 0x6f, 0x6e, /* notation */
0x49, 0x6e, 0x64, 0x65, 0x78, 0x28, 0x51, 0x75, /* Index(Qu */
0x65, 0x73, 0x74, 0x69, 0x6f, 0x6e, 0x2e, 0x74, /* estion.t */
0x79, 0x70, 0x65, 0x29, 0x2e, 0x69, 0x74, 0x65, /* ype).ite */
0x72, 0x61, 0x74, 0x6f, 0x72, 0x28, 0x29, 0x3b, /* rator(); */
0x0a, 0x20, 0x20, 0x20, 0x20, 0x2f, 0x2f, 0x20, /* .    //  */
0x53, 0x74, 0x72, 0x69, 0x6e, 0x67, 0x20, 0x44, /* String D */
0x6f, 0x63, 0x20, 0x3d, 0x20, 0x61, 0x4a, 0x43, /* oc = aJC */
0x61, 0x73, 0x2e, 0x67, 0x65, 0x74, 0x44, 0x6f, /* as.getDo */
0x63, 0x75, 0x6d, 0x65, 0x6e, 0x74, 0x54, 0x65, /* cumentTe */
0x78, 0x74, 0x28, 0x29, 0x3b, 0x0a, 0x20, 0x20, /* xt();.   */
0x20, 0x20, 0x51, 0x75, 0x65, 0x73, 0x74, 0x69, /*   Questi */
0x6f, 0x6e, 0x20, 0x71, 0x75, 0x65, 0x73, 0x74, /* on quest */
0x69, 0x6f, 0x6e, 0x54, 0x79, 0x70, 0x65, 0x53, /* ionTypeS */
0x79, 0x73, 0x20, 0x3d, 0x20, 0x6e, 0x75, 0x6c, /* ys = nul */
0x6c, 0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x69, /* l;.    i */
0x66, 0x20, 0x28, 0x69, 0x74, 0x2e, 0x68, 0x61, /* f (it.ha */
0x73, 0x4e, 0x65, 0x78, 0x74, 0x28, 0x29, 0x29, /* sNext()) */
0x20, 0x7b, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, /*  {.      */
0x20, 0x71, 0x75, 0x65, 0x73, 0x74, 0x69, 0x6f, /*  questio */
0x6e, 0x54, 0x79, 0x70, 0x65, 0x53, 0x79, 0x73, /* nTypeSys */
0x20, 0x3d, 0x20, 0x28, 0x51, 0x75, 0x65, 0x73, /*  = (Ques */
0x74, 0x69, 0x6f, 0x6e, 0x29, 0x20, 0x69, 0x74, /* tion) it */
```

```
0x2e, 0x6e, 0x65, 0x78, 0x74, 0x28, 0x29, 0x3b, /* .next(); */
0x0a, 0x20, 0x20, 0x20, 0x20, 0x7d, 0x0a, 0x20, /* .    }.  */
0x20, 0x20, 0x20, 0x53, 0x74, 0x72, 0x69, 0x6e, /*    Strin */
0x67, 0x20, 0x74, 0x65, 0x78, 0x74, 0x20, 0x3d, /* g text = */
0x20, 0x71, 0x75, 0x65, 0x73, 0x74, 0x69, 0x6f, /*  questio */
0x6e, 0x54, 0x79, 0x70, 0x65, 0x53, 0x79, 0x73, /* nTypeSys */
0x2e, 0x67, 0x65, 0x74, 0x54, 0x65, 0x78, 0x74, /* .getText */
0x28, 0x29, 0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, /* ();.     */
0x43, 0x6f, 0x6e, 0x63, 0x65, 0x70, 0x74, 0x20, /* Concept  */
0x63, 0x6f, 0x6e, 0x63, 0x65, 0x70, 0x74, 0x54, /* conceptT */
0x79, 0x70, 0x65, 0x53, 0x79, 0x73, 0x20, 0x3d, /* ypeSys = */
0x20, 0x6e, 0x75, 0x6c, 0x6c, 0x3b, 0x0a, 0x20, /*  null;.  */
0x20, 0x20, 0x20, 0x2f, 0x2f, 0x20, 0x53, 0x74, /*    // St */
0x72, 0x69, 0x6e, 0x67, 0x4c, 0x69, 0x73, 0x74, /* ringList */
0x20, 0x63, 0x6f, 0x6e, 0x63, 0x65, 0x70, 0x74, /*  concept */
0x53, 0x74, 0x72, 0x69, 0x6e, 0x67, 0x4c, 0x69, /* StringLi */
0x73, 0x74, 0x20, 0x3d, 0x20, 0x6e, 0x75, 0x6c, /* st = nul */
0x6c, 0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x2f, /* l;.    / */
0x2f, 0x20, 0x46, 0x53, 0x4c, 0x69, 0x73, 0x74, /* / FSList */
0x20, 0x6d, 0x65, 0x6e, 0x74, 0x69, 0x6f, 0x6e, /*  mention */
0x4c, 0x69, 0x73, 0x74, 0x20, 0x3d, 0x20, 0x6e, /* List = n */
0x75, 0x6c, 0x6c, 0x3b, 0x0a, 0x20, 0x20, 0x20, /* ull;.    */
0x20, 0x4c, 0x69, 0x73, 0x74, 0x3c, 0x53, 0x74, /*  List<St */
0x72, 0x69, 0x6e, 0x67, 0x3e, 0x20, 0x63, 0x6f, /* ring> co */
0x6e, 0x63, 0x65, 0x70, 0x74, 0x4c, 0x69, 0x73, /* nceptLis */
0x74, 0x20, 0x3d, 0x20, 0x6e, 0x75, 0x6c, 0x6c, /* t = null */
0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x4c, 0x69, /* ;.    Li */
0x73, 0x74, 0x3c, 0x44, 0x6f, 0x75, 0x62, 0x6c, /* st<Doubl */
0x65, 0x3e, 0x20, 0x63, 0x6f, 0x6e, 0x66, 0x69, /* e> confi */
0x64, 0x65, 0x6e, 0x63, 0x65, 0x4c, 0x69, 0x73, /* denceLis */
0x74, 0x20, 0x3d, 0x20, 0x6e, 0x75, 0x6c, 0x6c, /* t = null */
0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x65, 0x64, /* ;.    ed */
0x75, 0x2e, 0x63, 0x6d, 0x75, 0x2e, 0x6c, 0x74, /* u.cmu.lt */
0x69, 0x2e, 0x6f, 0x61, 0x71, 0x61, 0x2e, 0x74, /* i.oaqa.t */
0x79, 0x70, 0x65, 0x2e, 0x72, 0x65, 0x74, 0x72, /* ype.retr */
0x69, 0x65, 0x76, 0x61, 0x6c, 0x2e, 0x44, 0x6f, /* ieval.Do */
0x63, 0x75, 0x6d, 0x65, 0x6e, 0x74, 0x20, 0x64, /* cument d */
0x6f, 0x63, 0x75, 0x6d, 0x65, 0x6e, 0x74, 0x54, /* ocumentT */
0x79, 0x70, 0x65, 0x53, 0x79, 0x73, 0x20, 0x3d, /* ypeSys = */
0x20, 0x6e, 0x75, 0x6c, 0x6c, 0x3b, 0x0a, 0x20, /*  null;.  */
0x20, 0x20, 0x20, 0x2f, 0x2f, 0x20, 0x53, 0x74, /*    // St */
0x72, 0x69, 0x6e, 0x67, 0x4c, 0x69, 0x73, 0x74, /* ringList */
0x20, 0x64, 0x6f, 0x63, 0x75, 0x6d, 0x65, 0x6e, /*  documen */
0x74, 0x53, 0x74, 0x72, 0x69, 0x6e, 0x67, 0x4c, /* tStringL */
0x69, 0x73, 0x74, 0x20, 0x3d, 0x20, 0x6e, 0x75, /* ist = nu */
0x6c, 0x6c, 0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, /* ll;.     */
0x54, 0x72, 0x69, 0x70, 0x6c, 0x65, 0x20, 0x74, /* Triple t */
0x72, 0x69, 0x70, 0x6c, 0x65, 0x54, 0x79, 0x70, /* ripleTyp */
0x65, 0x53, 0x79, 0x73, 0x20, 0x3d, 0x20, 0x6e, /* eSys = n */
0x75, 0x6c, 0x6c, 0x3b, 0x0a, 0x20, 0x20, 0x20, /* ull;.    */
```

```
0x20, 0x74, 0x72, 0x79, 0x20, 0x7b, 0x0a, 0x20, /*  try {.  */
0x20, 0x20, 0x20, 0x20, 0x20, 0x4f, 0x6e, 0x74, /*      Ont */
0x6f, 0x6c, 0x6f, 0x67, 0x79, 0x53, 0x65, 0x72, /* ologySer */
0x76, 0x69, 0x63, 0x65, 0x52, 0x65, 0x73, 0x70, /* viceResp */
0x6f, 0x6e, 0x73, 0x65, 0x2e, 0x52, 0x65, 0x73, /* onse.Res */
0x75, 0x6c, 0x74, 0x20, 0x64, 0x69, 0x73, 0x65, /* ult dise */
0x61, 0x73, 0x65, 0x4f, 0x6e, 0x74, 0x6f, 0x6c, /* aseOntol */
0x6f, 0x67, 0x79, 0x52, 0x65, 0x73, 0x75, 0x6c, /* ogyResul */
0x74, 0x20, 0x3d, 0x20, 0x73, 0x65, 0x72, 0x76, /* t = serv */
0x69, 0x63, 0x65, 0x0a, 0x20, 0x20, 0x20, 0x20, /* ice.     */
0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, /*          */
0x20, 0x20, 0x2e, 0x66, 0x69, 0x6e, 0x64, 0x44, /*   .findD */
0x69, 0x73, 0x65, 0x61, 0x73, 0x65, 0x4f, 0x6e, /* iseaseOn */
0x74, 0x6f, 0x6c, 0x6f, 0x67, 0x79, 0x45, 0x6e, /* tologyEn */
0x74, 0x69, 0x74, 0x69, 0x65, 0x73, 0x50, 0x61, /* titiesPa */
0x67, 0x65, 0x64, 0x28, 0x74, 0x65, 0x78, 0x74, /* ged(text */
0x2c, 0x20, 0x30, 0x29, 0x3b, 0x0a, 0x20, 0x20, /* , 0);.   */
0x20, 0x20, 0x20, 0x20, 0x63, 0x6f, 0x6e, 0x63, /*     conc */
0x65, 0x70, 0x74, 0x4c, 0x69, 0x73, 0x74, 0x20, /* eptList  */
0x3d, 0x20, 0x6e, 0x65, 0x77, 0x20, 0x41, 0x72, /* = new Ar */
0x72, 0x61, 0x79, 0x4c, 0x69, 0x73, 0x74, 0x3c, /* rayList< */
0x53, 0x74, 0x72, 0x69, 0x6e, 0x67, 0x3e, 0x28, /* String>( */
0x29, 0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, /* );.      */
0x20, 0x63, 0x6f, 0x6e, 0x66, 0x69, 0x64, 0x65, /*  confide */
0x6e, 0x63, 0x65, 0x4c, 0x69, 0x73, 0x74, 0x20, /* nceList  */
0x3d, 0x20, 0x6e, 0x65, 0x77, 0x20, 0x41, 0x72, /* = new Ar */
0x72, 0x61, 0x79, 0x4c, 0x69, 0x73, 0x74, 0x3c, /* rayList< */
0x44, 0x6f, 0x75, 0x62, 0x6c, 0x65, 0x3e, 0x28, /* Double>( */
0x29, 0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, /* );.      */
0x20, 0x63, 0x6f, 0x6e, 0x63, 0x65, 0x70, 0x74, /*  concept */
0x54, 0x79, 0x70, 0x65, 0x53, 0x79, 0x73, 0x20, /* TypeSys  */
0x3d, 0x20, 0x6e, 0x65, 0x77, 0x20, 0x43, 0x6f, /* = new Co */
0x6e, 0x63, 0x65, 0x70, 0x74, 0x28, 0x61, 0x4a, /* ncept(aJ */
0x43, 0x61, 0x73, 0x29, 0x3b, 0x0a, 0x20, 0x20, /* Cas);.   */
0x20, 0x20, 0x20, 0x20, 0x66, 0x6f, 0x72, 0x20, /*     for  */
0x28, 0x4f, 0x6e, 0x74, 0x6f, 0x6c, 0x6f, 0x67, /* (Ontolog */
0x79, 0x53, 0x65, 0x72, 0x76, 0x69, 0x63, 0x65, /* yService */
0x52, 0x65, 0x73, 0x70, 0x6f, 0x6e, 0x73, 0x65, /* Response */
0x2e, 0x46, 0x69, 0x6e, 0x64, 0x69, 0x6e, 0x67, /* .Finding */
0x20, 0x66, 0x69, 0x6e, 0x64, 0x69, 0x6e, 0x67, /*  finding */
0x20, 0x3a, 0x20, 0x64, 0x69, 0x73, 0x65, 0x61, /*  : disea */
0x73, 0x65, 0x4f, 0x6e, 0x74, 0x6f, 0x6c, 0x6f, /* seOntolo */
0x67, 0x79, 0x52, 0x65, 0x73, 0x75, 0x6c, 0x74, /* gyResult */
0x2e, 0x67, 0x65, 0x74, 0x46, 0x69, 0x6e, 0x64, /* .getFind */
0x69, 0x6e, 0x67, 0x73, 0x28, 0x29, 0x29, 0x20, /* ings())  */
0x7b, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, /* {.       */
0x20, 0x20, 0x63, 0x6f, 0x6e, 0x63, 0x65, 0x70, /*   concep */
0x74, 0x4c, 0x69, 0x73, 0x74, 0x2e, 0x61, 0x64, /* tList.ad */
0x64, 0x28, 0x66, 0x69, 0x6e, 0x64, 0x69, 0x6e, /* d(findin */
0x67, 0x2e, 0x67, 0x65, 0x74, 0x43, 0x6f, 0x6e, /* g.getCon */
```

```
0x63, 0x65, 0x70, 0x74, 0x28, 0x29, 0x2e, 0x67, /* cept().g */
0x65, 0x74, 0x55, 0x72, 0x69, 0x28, 0x29, 0x29, /* etUri()) */
0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, /* ;.       */
0x20, 0x20, 0x63, 0x6f, 0x6e, 0x66, 0x69, 0x64, /*   confid */
0x65, 0x6e, 0x63, 0x65, 0x4c, 0x69, 0x73, 0x74, /* enceList */
0x2e, 0x61, 0x64, 0x64, 0x28, 0x66, 0x69, 0x6e, /* .add(fin */
0x64, 0x69, 0x6e, 0x67, 0x2e, 0x67, 0x65, 0x74, /* ding.get */
0x53, 0x63, 0x6f, 0x72, 0x65, 0x28, 0x29, 0x29, /* Score()) */
0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, /* ;.       */
0x7d, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, /* }.       */
0x63, 0x6f, 0x6e, 0x63, 0x65, 0x70, 0x74, 0x54, /* conceptT */
0x79, 0x70, 0x65, 0x53, 0x79, 0x73, 0x2e, 0x73, /* ypeSys.s */
0x65, 0x74, 0x4e, 0x61, 0x6d, 0x65, 0x28, 0x22, /* etName(" */
0x44, 0x69, 0x73, 0x65, 0x61, 0x73, 0x65, 0x20, /* Disease  */
0x4f, 0x6e, 0x74, 0x6f, 0x6c, 0x6f, 0x67, 0x79, /* Ontology */
0x22, 0x29, 0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, /* ");.     */
0x20, 0x20, 0x2f, 0x2f, 0x63, 0x6f, 0x6e, 0x63, /*   //conc */
0x65, 0x70, 0x74, 0x54, 0x79, 0x70, 0x65, 0x53, /* eptTypeS */
0x79, 0x73, 0x2e, 0x73, 0x65, 0x74, 0x55, 0x72, /* ys.setUr */
0x69, 0x73, 0x28, 0x55, 0x74, 0x69, 0x6c, 0x73, /* is(Utils */
0x2e, 0x63, 0x72, 0x65, 0x61, 0x74, 0x65, 0x53, /* .createS */
0x74, 0x72, 0x69, 0x6e, 0x67, 0x4c, 0x69, 0x73, /* tringLis */
0x74, 0x28, 0x61, 0x4a, 0x43, 0x61, 0x73, 0x2c, /* t(aJCas, */
0x20, 0x63, 0x6f, 0x6e, 0x63, 0x65, 0x70, 0x74, /*  concept */
0x4c, 0x69, 0x73, 0x74, 0x29, 0x29, 0x3b, 0x0a, /* List));. */
0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x2f, 0x2f, /*       // */
0x63, 0x6f, 0x6e, 0x63, 0x65, 0x70, 0x74, 0x54, /* conceptT */
0x79, 0x70, 0x65, 0x53, 0x79, 0x73, 0x2e, 0x73, /* ypeSys.s */
0x65, 0x74, 0x4d, 0x65, 0x6e, 0x74, 0x69, 0x6f, /* etMentio */
0x6e, 0x73, 0x28, 0x55, 0x74, 0x69, 0x6c, 0x73, /* ns(Utils */
0x2e, 0x66, 0x72, 0x6f, 0x6d, 0x43, 0x6f, 0x6c, /* .fromCol */
0x6c, 0x65, 0x63, 0x74, 0x69, 0x6f, 0x6e, 0x54, /* lectionT */
0x6f, 0x46, 0x53, 0x4c, 0x69, 0x73, 0x74, 0x28, /* oFSList( */
0x61, 0x4a, 0x43, 0x61, 0x73, 0x2c, 0x20, 0x28, /* aJCas, ( */
0x43, 0x6f, 0x6c, 0x6c, 0x65, 0x63, 0x74, 0x69, /* Collecti */
0x6f, 0x6e                                      /* on */
};

/* Frame (1266 bytes) */
static const unsigned char pkt15[1266] = {
0xd4, 0xbe, 0xd9, 0x50, 0xfa, 0xb2, 0x40, 0x3c, /* ...P..@< */
0xfc, 0x01, 0x04, 0x85, 0x08, 0x00, 0x45, 0x08, /* ......E. */
0x04, 0xe4, 0x72, 0x46, 0x40, 0x00, 0x40, 0x06, /* ..rF@.@. */
0x40, 0x72, 0xc0, 0xa8, 0x01, 0x02, 0xc0, 0xa8, /* @r...... */
0x01, 0x01, 0x00, 0x14, 0xdf, 0x75, 0xe1, 0x89, /* .....u.. */
0xd2, 0x92, 0x28, 0x0a, 0x7e, 0xea, 0x80, 0x18, /* ..(.~... */
0x01, 0xc9, 0xd6, 0xe6, 0x00, 0x00, 0x01, 0x01, /* ........ */
0x08, 0x0a, 0x00, 0xf8, 0xb5, 0x03, 0x00, 0x07, /* ........ */
0x27, 0x99, 0x29, 0x20, 0x63, 0x6f, 0x6e, 0x66, /* '.) conf */
0x69, 0x64, 0x65, 0x6e, 0x63, 0x65, 0x4c, 0x69, /* idenceLi */
```

```
0x73, 0x74, 0x29, 0x29, 0x3b, 0x0a, 0x20, 0x20, /* st));.   */
0x20, 0x20, 0x20, 0x20, 0x63, 0x6f, 0x6e, 0x63, /*     conc */
0x65, 0x70, 0x74, 0x54, 0x79, 0x70, 0x65, 0x53, /* eptTypeS */
0x79, 0x73, 0x2e, 0x61, 0x64, 0x64, 0x54, 0x6f, /* ys.addTo */
0x49, 0x6e, 0x64, 0x65, 0x78, 0x65, 0x73, 0x28, /* Indexes( */
0x61, 0x4a, 0x43, 0x61, 0x73, 0x29, 0x3b, 0x0a, /* aJCas);. */
0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x63, 0x6f, /*       co */
0x6e, 0x63, 0x65, 0x70, 0x74, 0x4c, 0x69, 0x73, /* nceptLis */
0x74, 0x20, 0x3d, 0x20, 0x6e, 0x65, 0x77, 0x20, /* t = new  */
0x41, 0x72, 0x72, 0x61, 0x79, 0x4c, 0x69, 0x73, /* ArrayLis */
0x74, 0x3c, 0x53, 0x74, 0x72, 0x69, 0x6e, 0x67, /* t<String */
0x3e, 0x28, 0x29, 0x3b, 0x0a, 0x20, 0x20, 0x20, /* >();.    */
0x20, 0x20, 0x20, 0x63, 0x6f, 0x6e, 0x66, 0x69, /*    confi */
0x64, 0x65, 0x6e, 0x63, 0x65, 0x4c, 0x69, 0x73, /* denceLis */
0x74, 0x20, 0x3d, 0x20, 0x6e, 0x65, 0x77, 0x20, /* t = new  */
0x41, 0x72, 0x72, 0x61, 0x79, 0x4c, 0x69, 0x73, /* ArrayLis */
0x74, 0x3c, 0x44, 0x6f, 0x75, 0x62, 0x6c, 0x65, /* t<Double */
0x3e, 0x28, 0x29, 0x3b, 0x0a, 0x20, 0x20, 0x20, /* >();.    */
0x20, 0x20, 0x20, 0x63, 0x6f, 0x6e, 0x63, 0x65, /*    conce */
0x70, 0x74, 0x54, 0x79, 0x70, 0x65, 0x53, 0x79, /* ptTypeSy */
0x73, 0x20, 0x3d, 0x20, 0x6e, 0x65, 0x77, 0x20, /* s = new  */
0x43, 0x6f, 0x6e, 0x63, 0x65, 0x70, 0x74, 0x28, /* Concept( */
0x61, 0x4a, 0x43, 0x61, 0x73, 0x29, 0x3b, 0x0a, /* aJCas);. */
0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x4f, 0x6e, /*       On */
0x74, 0x6f, 0x6c, 0x6f, 0x67, 0x79, 0x53, 0x65, /* tologySe */
0x72, 0x76, 0x69, 0x63, 0x65, 0x52, 0x65, 0x73, /* rviceRes */
0x70, 0x6f, 0x6e, 0x73, 0x65, 0x2e, 0x52, 0x65, /* ponse.Re */
0x73, 0x75, 0x6c, 0x74, 0x20, 0x67, 0x65, 0x6e, /* sult gen */
0x65, 0x4f, 0x6e, 0x74, 0x6f, 0x6c, 0x6f, 0x67, /* eOntolog */
0x79, 0x52, 0x65, 0x73, 0x75, 0x6c, 0x74, 0x20, /* yResult  */
0x3d, 0x20, 0x73, 0x65, 0x72, 0x76, 0x69, 0x63, /* = servic */
0x65, 0x2e, 0x66, 0x69, 0x6e, 0x64, 0x47, 0x65, /* e.findGe */
0x6e, 0x65, 0x4f, 0x6e, 0x74, 0x6f, 0x6c, 0x6f, /* neOntolo */
0x67, 0x79, 0x45, 0x6e, 0x74, 0x69, 0x74, 0x69, /* gyEntiti */
0x65, 0x73, 0x50, 0x61, 0x67, 0x65, 0x64, 0x28, /* esPaged( */
0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, /* .        */
0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x74, /*        t */
0x65, 0x78, 0x74, 0x2c, 0x20, 0x30, 0x2c, 0x20, /* ext, 0,  */
0x31, 0x30, 0x29, 0x3b, 0x0a, 0x20, 0x20, 0x20, /* 10);.    */
0x20, 0x20, 0x20, 0x66, 0x6f, 0x72, 0x20, 0x28, /*    for ( */
0x4f, 0x6e, 0x74, 0x6f, 0x6c, 0x6f, 0x67, 0x79, /* Ontology */
0x53, 0x65, 0x72, 0x76, 0x69, 0x63, 0x65, 0x52, /* ServiceR */
0x65, 0x73, 0x70, 0x6f, 0x6e, 0x73, 0x65, 0x2e, /* esponse. */
0x46, 0x69, 0x6e, 0x64, 0x69, 0x6e, 0x67, 0x20, /* Finding  */
0x66, 0x69, 0x6e, 0x64, 0x69, 0x6e, 0x67, 0x20, /* finding  */
0x3a, 0x20, 0x67, 0x65, 0x6e, 0x65, 0x4f, 0x6e, /* : geneOn */
0x74, 0x6f, 0x6c, 0x6f, 0x67, 0x79, 0x52, 0x65, /* tologyRe */
0x73, 0x75, 0x6c, 0x74, 0x2e, 0x67, 0x65, 0x74, /* sult.get */
0x46, 0x69, 0x6e, 0x64, 0x69, 0x6e, 0x67, 0x73, /* Findings */
0x28, 0x29, 0x29, 0x20, 0x7b, 0x0a, 0x20, 0x20, /* ()) {.   */
```

```
0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x63, 0x6f, /*       co */
0x6e, 0x63, 0x65, 0x70, 0x74, 0x4c, 0x69, 0x73, /* nceptLis */
0x74, 0x2e, 0x61, 0x64, 0x64, 0x28, 0x66, 0x69, /* t.add(fi */
0x6e, 0x64, 0x69, 0x6e, 0x67, 0x2e, 0x67, 0x65, /* nding.ge */
0x74, 0x43, 0x6f, 0x6e, 0x63, 0x65, 0x70, 0x74, /* tConcept */
0x28, 0x29, 0x2e, 0x67, 0x65, 0x74, 0x55, 0x72, /* ().getUr */
0x69, 0x28, 0x29, 0x29, 0x3b, 0x0a, 0x20, 0x20, /* i());.   */
0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x63, 0x6f, /*       co */
0x6e, 0x66, 0x69, 0x64, 0x65, 0x6e, 0x63, 0x65, /* nfidence */
0x4c, 0x69, 0x73, 0x74, 0x2e, 0x61, 0x64, 0x64, /* List.add */
0x28, 0x66, 0x69, 0x6e, 0x64, 0x69, 0x6e, 0x67, /* (finding */
0x2e, 0x67, 0x65, 0x74, 0x53, 0x63, 0x6f, 0x72, /* .getScor */
0x65, 0x28, 0x29, 0x29, 0x3b, 0x0a, 0x20, 0x20, /* e());.   */
0x20, 0x20, 0x20, 0x20, 0x7d, 0x0a, 0x20, 0x20, /*     }.   */
0x20, 0x20, 0x20, 0x20, 0x63, 0x6f, 0x6e, 0x63, /*     conc */
0x65, 0x70, 0x74, 0x54, 0x79, 0x70, 0x65, 0x53, /* eptTypeS */
0x79, 0x73, 0x2e, 0x73, 0x65, 0x74, 0x4e, 0x61, /* ys.setNa */
0x6d, 0x65, 0x28, 0x22, 0x47, 0x65, 0x6e, 0x65, /* me("Gene */
0x20, 0x4f, 0x6e, 0x74, 0x6f, 0x6c, 0x6f, 0x67, /*  Ontolog */
0x79, 0x22, 0x29, 0x3b, 0x0a, 0x20, 0x20, 0x20, /* y");.    */
0x20, 0x20, 0x20, 0x2f, 0x2f, 0x63, 0x6f, 0x6e, /*    //con */
0x63, 0x65, 0x70, 0x74, 0x54, 0x79, 0x70, 0x65, /* ceptType */
0x53, 0x79, 0x73, 0x2e, 0x73, 0x65, 0x74, 0x55, /* Sys.setU */
0x72, 0x69, 0x73, 0x28, 0x55, 0x74, 0x69, 0x6c, /* ris(Util */
0x73, 0x2e, 0x63, 0x72, 0x65, 0x61, 0x74, 0x65, /* s.create */
0x53, 0x74, 0x72, 0x69, 0x6e, 0x67, 0x4c, 0x69, /* StringLi */
0x73, 0x74, 0x28, 0x61, 0x4a, 0x43, 0x61, 0x73, /* st(aJCas */
0x2c, 0x20, 0x63, 0x6f, 0x6e, 0x63, 0x65, 0x70, /* , concep */
0x74, 0x4c, 0x69, 0x73, 0x74, 0x29, 0x29, 0x3b, /* tList)); */
0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x2f, /* .      / */
0x2f, 0x63, 0x6f, 0x6e, 0x63, 0x65, 0x70, 0x74, /* /concept */
0x54, 0x79, 0x70, 0x65, 0x53, 0x79, 0x73, 0x2e, /* TypeSys. */
0x73, 0x65, 0x74, 0x4d, 0x65, 0x6e, 0x74, 0x69, /* setMenti */
0x6f, 0x6e, 0x73, 0x28, 0x55, 0x74, 0x69, 0x6c, /* ons(Util */
0x73, 0x2e, 0x66, 0x72, 0x6f, 0x6d, 0x43, 0x6f, /* s.fromCo */
0x6c, 0x6c, 0x65, 0x63, 0x74, 0x69, 0x6f, 0x6e, /* llection */
0x54, 0x6f, 0x46, 0x53, 0x4c, 0x69, 0x73, 0x74, /* ToFSList */
0x28, 0x61, 0x4a, 0x43, 0x61, 0x73, 0x2c, 0x20, /* (aJCas,  */
0x28, 0x43, 0x6f, 0x6c, 0x6c, 0x65, 0x63, 0x74, /* (Collect */
0x69, 0x6f, 0x6e, 0x29, 0x20, 0x63, 0x6f, 0x6e, /* ion) con */
0x66, 0x69, 0x64, 0x65, 0x6e, 0x63, 0x65, 0x4c, /* fidenceL */
0x69, 0x73, 0x74, 0x29, 0x29, 0x3b, 0x0a, 0x20, /* ist));.  */
0x20, 0x20, 0x20, 0x20, 0x20, 0x63, 0x6f, 0x6e, /*      con */
0x63, 0x65, 0x70, 0x74, 0x54, 0x79, 0x70, 0x65, /* ceptType */
0x53, 0x79, 0x73, 0x2e, 0x61, 0x64, 0x64, 0x54, /* Sys.addT */
0x6f, 0x49, 0x6e, 0x64, 0x65, 0x78, 0x65, 0x73, /* oIndexes */
0x28, 0x61, 0x4a, 0x43, 0x61, 0x73, 0x29, 0x3b, /* (aJCas); */
0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x63, /* .      c */
0x6f, 0x6e, 0x63, 0x65, 0x70, 0x74, 0x4c, 0x69, /* onceptLi */
0x73, 0x74, 0x20, 0x3d, 0x20, 0x6e, 0x65, 0x77, /* st = new */
```

```
0x20, 0x41, 0x72, 0x72, 0x61, 0x79, 0x4c, 0x69, /*  ArrayLi */
0x73, 0x74, 0x3c, 0x53, 0x74, 0x72, 0x69, 0x6e, /* st<Strin */
0x67, 0x3e, 0x28, 0x29, 0x3b, 0x0a, 0x20, 0x20, /* g>();.   */
0x20, 0x20, 0x20, 0x20, 0x63, 0x6f, 0x6e, 0x66, /*     conf */
0x69, 0x64, 0x65, 0x6e, 0x63, 0x65, 0x4c, 0x69, /* idenceLi */
0x73, 0x74, 0x20, 0x3d, 0x20, 0x6e, 0x65, 0x77, /* st = new */
0x20, 0x41, 0x72, 0x72, 0x61, 0x79, 0x4c, 0x69, /*  ArrayLi */
0x73, 0x74, 0x3c, 0x44, 0x6f, 0x75, 0x62, 0x6c, /* st<Doubl */
0x65, 0x3e, 0x28, 0x29, 0x3b, 0x0a, 0x20, 0x20, /* e>();.   */
0x20, 0x20, 0x20, 0x20, 0x63, 0x6f, 0x6e, 0x63, /*     conc */
0x65, 0x70, 0x74, 0x54, 0x79, 0x70, 0x65, 0x53, /* eptTypeS */
0x79, 0x73, 0x20, 0x3d, 0x20, 0x6e, 0x65, 0x77, /* ys = new */
0x20, 0x43, 0x6f, 0x6e, 0x63, 0x65, 0x70, 0x74, /*  Concept */
0x28, 0x61, 0x4a, 0x43, 0x61, 0x73, 0x29, 0x3b, /* (aJCas); */
0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x4f, /* .      O */
0x6e, 0x74, 0x6f, 0x6c, 0x6f, 0x67, 0x79, 0x53, /* ntologyS */
0x65, 0x72, 0x76, 0x69, 0x63, 0x65, 0x52, 0x65, /* erviceRe */
0x73, 0x70, 0x6f, 0x6e, 0x73, 0x65, 0x2e, 0x52, /* sponse.R */
0x65, 0x73, 0x75, 0x6c, 0x74, 0x20, 0x6a, 0x6f, /* esult jo */
0x63, 0x68, 0x65, 0x6d, 0x52, 0x65, 0x73, 0x75, /* chemResu */
0x6c, 0x74, 0x20, 0x3d, 0x20, 0x73, 0x65, 0x72, /* lt = ser */
0x76, 0x69, 0x63, 0x65, 0x2e, 0x66, 0x69, 0x6e, /* vice.fin */
0x64, 0x4a, 0x6f, 0x63, 0x68, 0x65, 0x6d, 0x45, /* dJochemE */
0x6e, 0x74, 0x69, 0x74, 0x69, 0x65, 0x73, 0x50, /* ntitiesP */
0x61, 0x67, 0x65, 0x64, 0x28, 0x74, 0x65, 0x78, /* aged(tex */
0x74, 0x2c, 0x20, 0x30, 0x29, 0x3b, 0x0a, 0x20, /* t, 0);.  */
0x20, 0x20, 0x20, 0x20, 0x20, 0x66, 0x6f, 0x72, /*      for */
0x20, 0x28, 0x4f, 0x6e, 0x74, 0x6f, 0x6c, 0x6f, /*  (Ontolo */
0x67, 0x79, 0x53, 0x65, 0x72, 0x76, 0x69, 0x63, /* gyServic */
0x65, 0x52, 0x65, 0x73, 0x70, 0x6f, 0x6e, 0x73, /* eRespons */
0x65, 0x2e, 0x46, 0x69, 0x6e, 0x64, 0x69, 0x6e, /* e.Findin */
0x67, 0x20, 0x66, 0x69, 0x6e, 0x64, 0x69, 0x6e, /* g findin */
0x67, 0x20, 0x3a, 0x20, 0x6a, 0x6f, 0x63, 0x68, /* g : joch */
0x65, 0x6d, 0x52, 0x65, 0x73, 0x75, 0x6c, 0x74, /* emResult */
0x2e, 0x67, 0x65, 0x74, 0x46, 0x69, 0x6e, 0x64, /* .getFind */
0x69, 0x6e, 0x67, 0x73, 0x28, 0x29, 0x29, 0x20, /* ings())  */
0x7b, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, /* {.       */
0x20, 0x20, 0x63, 0x6f, 0x6e, 0x63, 0x65, 0x70, /*   concep */
0x74, 0x4c, 0x69, 0x73, 0x74, 0x2e, 0x61, 0x64, /* tList.ad */
0x64, 0x28, 0x66, 0x69, 0x6e, 0x64, 0x69, 0x6e, /* d(findin */
0x67, 0x2e, 0x67, 0x65, 0x74, 0x43, 0x6f, 0x6e, /* g.getCon */
0x63, 0x65, 0x70, 0x74, 0x28, 0x29, 0x2e, 0x67, /* cept().g */
0x65, 0x74, 0x55, 0x72, 0x69, 0x28, 0x29, 0x29, /* etUri()) */
0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, /* ;.       */
0x20, 0x20, 0x63, 0x6f, 0x6e, 0x66, 0x69, 0x64, /*   confid */
0x65, 0x6e, 0x63, 0x65, 0x4c, 0x69, 0x73, 0x74, /* enceList */
0x2e, 0x61, 0x64, 0x64, 0x28, 0x66, 0x69, 0x6e, /* .add(fin */
0x64, 0x69, 0x6e, 0x67, 0x2e, 0x67, 0x65, 0x74, /* ding.get */
0x53, 0x63                                      /* Sc */
};
```

```
/* Frame (1514 bytes) */
static const unsigned char pkt17[1514] = {
0xd4, 0xbe, 0xd9, 0x50, 0xfa, 0xb2, 0x40, 0x3c, /* ...P..@< */
0xfc, 0x01, 0x04, 0x85, 0x08, 0x00, 0x45, 0x08, /* ......E. */
0x05, 0xdc, 0x72, 0x47, 0x40, 0x00, 0x40, 0x06, /* ..rG@.@. */
0x3f, 0x79, 0xc0, 0xa8, 0x01, 0x02, 0xc0, 0xa8, /* ?y...... */
0x01, 0x01, 0x00, 0x14, 0xdf, 0x75, 0xe1, 0x89, /* .....u.. */
0xd7, 0x42, 0x28, 0x0a, 0x7e, 0xea, 0x80, 0x10, /* .B(.~... */
0x01, 0xc9, 0x58, 0x39, 0x00, 0x00, 0x01, 0x01, /* ..X9.... */
0x08, 0x0a, 0x00, 0xf8, 0xb5, 0x03, 0x00, 0x07, /* ........ */
0x27, 0x99, 0x6f, 0x72, 0x65, 0x28, 0x29, 0x29, /* '.ore()) */
0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, /* ;.      */
0x7d, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, /* }.      */
0x63, 0x6f, 0x6e, 0x63, 0x65, 0x70, 0x74, 0x54, /* conceptT */
0x79, 0x70, 0x65, 0x53, 0x79, 0x73, 0x2e, 0x73, /* ypeSys.s */
0x65, 0x74, 0x4e, 0x61, 0x6d, 0x65, 0x28, 0x22, /* etName(" */
0x4a, 0x6f, 0x63, 0x68, 0x65, 0x6d, 0x22, 0x29, /* Jochem") */
0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, /* ;.      */
0x2f, 0x2f, 0x63, 0x6f, 0x6e, 0x63, 0x65, 0x70, /* //concep */
0x74, 0x54, 0x79, 0x70, 0x65, 0x53, 0x79, 0x73, /* tTypeSys */
0x2e, 0x73, 0x65, 0x74, 0x55, 0x72, 0x69, 0x73, /* .setUris */
0x28, 0x55, 0x74, 0x69, 0x6c, 0x73, 0x2e, 0x63, /* (Utils.c */
0x72, 0x65, 0x61, 0x74, 0x65, 0x53, 0x74, 0x72, /* reateStr */
0x69, 0x6e, 0x67, 0x4c, 0x69, 0x73, 0x74, 0x28, /* ingList( */
0x61, 0x4a, 0x43, 0x61, 0x73, 0x2c, 0x20, 0x63, /* aJCas, c */
0x6f, 0x6e, 0x63, 0x65, 0x70, 0x74, 0x4c, 0x69, /* onceptLi */
0x73, 0x74, 0x29, 0x29, 0x3b, 0x0a, 0x20, 0x20, /* st));.   */
0x20, 0x20, 0x20, 0x20, 0x2f, 0x2f, 0x63, 0x6f, /*     //co */
0x6e, 0x63, 0x65, 0x70, 0x74, 0x54, 0x79, 0x70, /* nceptTyp */
0x65, 0x53, 0x79, 0x73, 0x2e, 0x73, 0x65, 0x74, /* eSys.set */
0x4d, 0x65, 0x6e, 0x74, 0x69, 0x6f, 0x6e, 0x73, /* Mentions */
0x28, 0x55, 0x74, 0x69, 0x6c, 0x73, 0x2e, 0x66, /* (Utils.f */
0x72, 0x6f, 0x6d, 0x43, 0x6f, 0x6c, 0x6c, 0x65, /* romColle */
0x63, 0x74, 0x69, 0x6f, 0x6e, 0x54, 0x6f, 0x46, /* ctionToF */
0x53, 0x4c, 0x69, 0x73, 0x74, 0x28, 0x61, 0x4a, /* SList(aJ */
0x43, 0x61, 0x73, 0x2c, 0x20, 0x28, 0x43, 0x6f, /* Cas, (Co */
0x6c, 0x6c, 0x65, 0x63, 0x74, 0x69, 0x6f, 0x6e, /* llection */
0x29, 0x20, 0x63, 0x6f, 0x6e, 0x66, 0x69, 0x64, /* ) confid */
0x65, 0x6e, 0x63, 0x65, 0x4c, 0x69, 0x73, 0x74, /* enceList */
0x29, 0x29, 0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, /* ));.     */
0x20, 0x20, 0x63, 0x6f, 0x6e, 0x63, 0x65, 0x70, /*   concep */
0x74, 0x54, 0x79, 0x70, 0x65, 0x53, 0x79, 0x73, /* tTypeSys */
0x2e, 0x61, 0x64, 0x64, 0x54, 0x6f, 0x49, 0x6e, /* .addToIn */
0x64, 0x65, 0x78, 0x65, 0x73, 0x28, 0x61, 0x4a, /* dexes(aJ */
0x43, 0x61, 0x73, 0x29, 0x3b, 0x0a, 0x20, 0x20, /* Cas);.   */
0x20, 0x20, 0x20, 0x20, 0x63, 0x6f, 0x6e, 0x63, /*     conc */
0x65, 0x70, 0x74, 0x4c, 0x69, 0x73, 0x74, 0x20, /* eptList  */
0x3d, 0x20, 0x6e, 0x65, 0x77, 0x20, 0x41, 0x72, /* = new Ar */
0x72, 0x61, 0x79, 0x4c, 0x69, 0x73, 0x74, 0x3c, /* rayList< */
```

```
0x53, 0x74, 0x72, 0x69, 0x6e, 0x67, 0x3e, 0x28, /* String>( */
0x29, 0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, /* );.      */
0x20, 0x63, 0x6f, 0x6e, 0x66, 0x69, 0x64, 0x65, /*  confide */
0x6e, 0x63, 0x65, 0x4c, 0x69, 0x73, 0x74, 0x20, /* nceList  */
0x3d, 0x20, 0x6e, 0x65, 0x77, 0x20, 0x41, 0x72, /* = new Ar */
0x72, 0x61, 0x79, 0x4c, 0x69, 0x73, 0x74, 0x3c, /* rayList< */
0x44, 0x6f, 0x75, 0x62, 0x6c, 0x65, 0x3e, 0x28, /* Double>( */
0x29, 0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, /* );.      */
0x20, 0x63, 0x6f, 0x6e, 0x63, 0x65, 0x70, 0x74, /*  concept */
0x54, 0x79, 0x70, 0x65, 0x53, 0x79, 0x73, 0x20, /* TypeSys  */
0x3d, 0x20, 0x6e, 0x65, 0x77, 0x20, 0x43, 0x6f, /* = new Co */
0x6e, 0x63, 0x65, 0x70, 0x74, 0x28, 0x61, 0x4a, /* ncept(aJ */
0x43, 0x61, 0x73, 0x29, 0x3b, 0x0a, 0x20, 0x20, /* Cas);.   */
0x20, 0x20, 0x20, 0x20, 0x4f, 0x6e, 0x74, 0x6f, /*     Onto */
0x6c, 0x6f, 0x67, 0x79, 0x53, 0x65, 0x72, 0x76, /* logyServ */
0x69, 0x63, 0x65, 0x52, 0x65, 0x73, 0x70, 0x6f, /* iceRespo */
0x6e, 0x73, 0x65, 0x2e, 0x52, 0x65, 0x73, 0x75, /* nse.Resu */
0x6c, 0x74, 0x20, 0x6d, 0x65, 0x73, 0x68, 0x52, /* lt meshR */
0x65, 0x73, 0x75, 0x6c, 0x74, 0x20, 0x3d, 0x20, /* esult =  */
0x73, 0x65, 0x72, 0x76, 0x69, 0x63, 0x65, 0x2e, /* service. */
0x66, 0x69, 0x6e, 0x64, 0x4d, 0x65, 0x73, 0x68, /* findMesh */
0x45, 0x6e, 0x74, 0x69, 0x74, 0x69, 0x65, 0x73, /* Entities */
0x50, 0x61, 0x67, 0x65, 0x64, 0x28, 0x74, 0x65, /* Paged(te */
0x78, 0x74, 0x2c, 0x20, 0x30, 0x29, 0x3b, 0x0a, /* xt, 0);. */
0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x66, 0x6f, /*       fo */
0x72, 0x20, 0x28, 0x4f, 0x6e, 0x74, 0x6f, 0x6c, /* r (Ontol */
0x6f, 0x67, 0x79, 0x53, 0x65, 0x72, 0x76, 0x69, /* ogyServi */
0x63, 0x65, 0x52, 0x65, 0x73, 0x70, 0x6f, 0x6e, /* ceRespon */
0x73, 0x65, 0x2e, 0x46, 0x69, 0x6e, 0x64, 0x69, /* se.Findi */
0x6e, 0x67, 0x20, 0x66, 0x69, 0x6e, 0x64, 0x69, /* ng findi */
0x6e, 0x67, 0x20, 0x3a, 0x20, 0x6d, 0x65, 0x73, /* ng : mes */
0x68, 0x52, 0x65, 0x73, 0x75, 0x6c, 0x74, 0x2e, /* hResult. */
0x67, 0x65, 0x74, 0x46, 0x69, 0x6e, 0x64, 0x69, /* getFindi */
0x6e, 0x67, 0x73, 0x28, 0x29, 0x29, 0x20, 0x7b, /* ngs()) { */
0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, /* .        */
0x20, 0x63, 0x6f, 0x6e, 0x63, 0x65, 0x70, 0x74, /*  concept */
0x4c, 0x69, 0x73, 0x74, 0x2e, 0x61, 0x64, 0x64, /* List.add */
0x28, 0x66, 0x69, 0x6e, 0x64, 0x69, 0x6e, 0x67, /* (finding */
0x2e, 0x67, 0x65, 0x74, 0x43, 0x6f, 0x6e, 0x63, /* .getConc */
0x65, 0x70, 0x74, 0x28, 0x29, 0x2e, 0x67, 0x65, /* ept().ge */
0x74, 0x55, 0x72, 0x69, 0x28, 0x29, 0x29, 0x3b, /* tUri()); */
0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, /* .        */
0x20, 0x63, 0x6f, 0x6e, 0x66, 0x69, 0x64, 0x65, /*  confide */
0x6e, 0x63, 0x65, 0x4c, 0x69, 0x73, 0x74, 0x2e, /* nceList. */
0x61, 0x64, 0x64, 0x28, 0x66, 0x69, 0x6e, 0x64, /* add(find */
0x69, 0x6e, 0x67, 0x2e, 0x67, 0x65, 0x74, 0x53, /* ing.getS */
0x63, 0x6f, 0x72, 0x65, 0x28, 0x29, 0x29, 0x3b, /* core()); */
0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x7d, /* .      } */
0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x63, /* .      c */
0x6f, 0x6e, 0x63, 0x65, 0x70, 0x74, 0x54, 0x79, /* onceptTy */
```

```
0x70, 0x65, 0x53, 0x79, 0x73, 0x2e, 0x73, 0x65, /* peSys.se */
0x74, 0x4e, 0x61, 0x6d, 0x65, 0x28, 0x22, 0x4d, /* tName("M */
0x65, 0x53, 0x48, 0x22, 0x29, 0x3b, 0x0a, 0x20, /* eSH");.  */
0x20, 0x20, 0x20, 0x20, 0x20, 0x2f, 0x2f, 0x63, /*      //c */
0x6f, 0x6e, 0x63, 0x65, 0x70, 0x74, 0x54, 0x79, /* onceptTy */
0x70, 0x65, 0x53, 0x79, 0x73, 0x2e, 0x73, 0x65, /* peSys.se */
0x74, 0x55, 0x72, 0x69, 0x73, 0x28, 0x55, 0x74, /* tUris(Ut */
0x69, 0x6c, 0x73, 0x2e, 0x63, 0x72, 0x65, 0x61, /* ils.crea */
0x74, 0x65, 0x53, 0x74, 0x72, 0x69, 0x6e, 0x67, /* teString */
0x4c, 0x69, 0x73, 0x74, 0x28, 0x61, 0x4a, 0x43, /* List(aJC */
0x61, 0x73, 0x2c, 0x20, 0x63, 0x6f, 0x6e, 0x63, /* as, conc */
0x65, 0x70, 0x74, 0x4c, 0x69, 0x73, 0x74, 0x29, /* eptList) */
0x29, 0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, /* );.      */
0x20, 0x2f, 0x2f, 0x63, 0x6f, 0x6e, 0x63, 0x65, /*  //conce */
0x70, 0x74, 0x54, 0x79, 0x70, 0x65, 0x53, 0x79, /* ptTypeSy */
0x73, 0x2e, 0x73, 0x65, 0x74, 0x4d, 0x65, 0x6e, /* s.setMen */
0x74, 0x69, 0x6f, 0x6e, 0x73, 0x28, 0x55, 0x74, /* tions(Ut */
0x69, 0x6c, 0x73, 0x2e, 0x66, 0x72, 0x6f, 0x6d, /* ils.from */
0x43, 0x6f, 0x6c, 0x6c, 0x65, 0x63, 0x74, 0x69, /* Collecti */
0x6f, 0x6e, 0x54, 0x6f, 0x46, 0x53, 0x4c, 0x69, /* onToFSLi */
0x73, 0x74, 0x28, 0x61, 0x4a, 0x43, 0x61, 0x73, /* st(aJCas */
0x2c, 0x20, 0x28, 0x43, 0x6f, 0x6c, 0x6c, 0x65, /* , (Colle */
0x63, 0x74, 0x69, 0x6f, 0x6e, 0x29, 0x20, 0x63, /* ction) c */
0x6f, 0x6e, 0x66, 0x69, 0x64, 0x65, 0x6e, 0x63, /* onfidenc */
0x65, 0x4c, 0x69, 0x73, 0x74, 0x29, 0x29, 0x3b, /* eList)); */
0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x63, /* .      c */
0x6f, 0x6e, 0x63, 0x65, 0x70, 0x74, 0x54, 0x79, /* onceptTy */
0x70, 0x65, 0x53, 0x79, 0x73, 0x2e, 0x61, 0x64, /* peSys.ad */
0x64, 0x54, 0x6f, 0x49, 0x6e, 0x64, 0x65, 0x78, /* dToIndex */
0x65, 0x73, 0x28, 0x61, 0x4a, 0x43, 0x61, 0x73, /* es(aJCas */
0x29, 0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, /* );.      */
0x20, 0x63, 0x6f, 0x6e, 0x63, 0x65, 0x70, 0x74, /*  concept */
0x4c, 0x69, 0x73, 0x74, 0x20, 0x3d, 0x20, 0x6e, /* List = n */
0x65, 0x77, 0x20, 0x41, 0x72, 0x72, 0x61, 0x79, /* ew Array */
0x4c, 0x69, 0x73, 0x74, 0x3c, 0x53, 0x74, 0x72, /* List<Str */
0x69, 0x6e, 0x67, 0x3e, 0x28, 0x29, 0x3b, 0x0a, /* ing>();. */
0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x63, 0x6f, /*       co */
0x6e, 0x66, 0x69, 0x64, 0x65, 0x6e, 0x63, 0x65, /* nfidence */
0x4c, 0x69, 0x73, 0x74, 0x20, 0x3d, 0x20, 0x6e, /* List = n */
0x65, 0x77, 0x20, 0x41, 0x72, 0x72, 0x61, 0x79, /* ew Array */
0x4c, 0x69, 0x73, 0x74, 0x3c, 0x44, 0x6f, 0x75, /* List<Dou */
0x62, 0x6c, 0x65, 0x3e, 0x28, 0x29, 0x3b, 0x0a, /* ble>();. */
0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x63, 0x6f, /*       co */
0x6e, 0x63, 0x65, 0x70, 0x74, 0x54, 0x79, 0x70, /* nceptTyp */
0x65, 0x53, 0x79, 0x73, 0x20, 0x3d, 0x20, 0x6e, /* eSys = n */
0x65, 0x77, 0x20, 0x43, 0x6f, 0x6e, 0x63, 0x65, /* ew Conce */
0x70, 0x74, 0x28, 0x61, 0x4a, 0x43, 0x61, 0x73, /* pt(aJCas */
0x29, 0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, /* );.      */
0x20, 0x4f, 0x6e, 0x74, 0x6f, 0x6c, 0x6f, 0x67, /*  Ontolog */
0x79, 0x53, 0x65, 0x72, 0x76, 0x69, 0x63, 0x65, /* yService */
```

```
0x52, 0x65, 0x73, 0x70, 0x6f, 0x6e, 0x73, 0x65, /* Response */
0x2e, 0x52, 0x65, 0x73, 0x75, 0x6c, 0x74, 0x20, /* .Result  */
0x75, 0x6e, 0x69, 0x70, 0x72, 0x6f, 0x74, 0x52, /* uniprotR */
0x65, 0x73, 0x75, 0x6c, 0x74, 0x20, 0x3d, 0x20, /* esult =  */
0x73, 0x65, 0x72, 0x76, 0x69, 0x63, 0x65, 0x2e, /* service. */
0x66, 0x69, 0x6e, 0x64, 0x55, 0x6e, 0x69, 0x70, /* findUnip */
0x72, 0x6f, 0x74, 0x45, 0x6e, 0x74, 0x69, 0x74, /* rotEntit */
0x69, 0x65, 0x73, 0x50, 0x61, 0x67, 0x65, 0x64, /* iesPaged */
0x28, 0x74, 0x65, 0x78, 0x74, 0x2c, 0x20, 0x30, /* (text, 0 */
0x29, 0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, /* );.      */
0x20, 0x66, 0x6f, 0x72, 0x20, 0x28, 0x4f, 0x6e, /*  for (On */
0x74, 0x6f, 0x6c, 0x6f, 0x67, 0x79, 0x53, 0x65, /* tologySe */
0x72, 0x76, 0x69, 0x63, 0x65, 0x52, 0x65, 0x73, /* rviceRes */
0x70, 0x6f, 0x6e, 0x73, 0x65, 0x2e, 0x46, 0x69, /* ponse.Fi */
0x6e, 0x64, 0x69, 0x6e, 0x67, 0x20, 0x66, 0x69, /* nding fi */
0x6e, 0x64, 0x69, 0x6e, 0x67, 0x20, 0x3a, 0x20, /* nding :  */
0x75, 0x6e, 0x69, 0x70, 0x72, 0x6f, 0x74, 0x52, /* uniprotR */
0x65, 0x73, 0x75, 0x6c, 0x74, 0x2e, 0x67, 0x65, /* esult.ge */
0x74, 0x46, 0x69, 0x6e, 0x64, 0x69, 0x6e, 0x67, /* tFinding */
0x73, 0x28, 0x29, 0x29, 0x20, 0x7b, 0x0a, 0x20, /* s()) {.  */
0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x63, /*        c */
0x6f, 0x6e, 0x63, 0x65, 0x70, 0x74, 0x4c, 0x69, /* onceptLi */
0x73, 0x74, 0x2e, 0x61, 0x64, 0x64, 0x28, 0x66, /* st.add(f */
0x69, 0x6e, 0x64, 0x69, 0x6e, 0x67, 0x2e, 0x67, /* inding.g */
0x65, 0x74, 0x43, 0x6f, 0x6e, 0x63, 0x65, 0x70, /* etConcep */
0x74, 0x28, 0x29, 0x2e, 0x67, 0x65, 0x74, 0x55, /* t().getU */
0x72, 0x69, 0x28, 0x29, 0x29, 0x3b, 0x0a, 0x20, /* ri());.  */
0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x63, /*        c */
0x6f, 0x6e, 0x66, 0x69, 0x64, 0x65, 0x6e, 0x63, /* onfidenc */
0x65, 0x4c, 0x69, 0x73, 0x74, 0x2e, 0x61, 0x64, /* eList.ad */
0x64, 0x28, 0x66, 0x69, 0x6e, 0x64, 0x69, 0x6e, /* d(findin */
0x67, 0x2e, 0x67, 0x65, 0x74, 0x53, 0x63, 0x6f, /* g.getSco */
0x72, 0x65, 0x28, 0x29, 0x29, 0x3b, 0x0a, 0x20, /* re());.  */
0x20, 0x20, 0x20, 0x20, 0x20, 0x7d, 0x0a, 0x20, /*      }.  */
0x20, 0x20, 0x20, 0x20, 0x20, 0x63, 0x6f, 0x6e, /*      con */
0x63, 0x65, 0x70, 0x74, 0x54, 0x79, 0x70, 0x65, /* ceptType */
0x53, 0x79, 0x73, 0x2e, 0x73, 0x65, 0x74, 0x4e, /* Sys.setN */
0x61, 0x6d, 0x65, 0x28, 0x22, 0x55, 0x6e, 0x69, /* ame("Uni */
0x50, 0x72, 0x6f, 0x74, 0x22, 0x29, 0x3b, 0x0a, /* Prot");. */
0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x2f, 0x2f, /*       // */
0x63, 0x6f, 0x6e, 0x63, 0x65, 0x70, 0x74, 0x54, /* conceptT */
0x79, 0x70, 0x65, 0x53, 0x79, 0x73, 0x2e, 0x73, /* ypeSys.s */
0x65, 0x74                                      /* et */
};

/* Frame (1831 bytes) */
static const unsigned char pkt19[1831] = {
0xd4, 0xbe, 0xd9, 0x50, 0xfa, 0xb2, 0x40, 0x3c, /* ...P..@< */
0xfc, 0x01, 0x04, 0x85, 0x08, 0x00, 0x45, 0x08, /* ......E. */
0x07, 0x19, 0x72, 0x48, 0x40, 0x00, 0x40, 0x06, /* ..rH@.@. */
```

```
0x3e, 0x3b, 0xc0, 0xa8, 0x01, 0x02, 0xc0, 0xa8, /* >;...... */
0x01, 0x01, 0x00, 0x14, 0xdf, 0x75, 0xe1, 0x89, /* .....u.. */
0xdc, 0xea, 0x28, 0x0a, 0x7e, 0xea, 0x80, 0x19, /* ..(.~... */
0x01, 0xc9, 0x8a, 0x5f, 0x00, 0x00, 0x01, 0x01, /* ..._.... */
0x08, 0x0a, 0x00, 0xf8, 0xb5, 0x03, 0x00, 0x07, /* ........ */
0x27, 0x99, 0x55, 0x72, 0x69, 0x73, 0x28, 0x55, /* '.Uris(U */
0x74, 0x69, 0x6c, 0x73, 0x2e, 0x63, 0x72, 0x65, /* tils.cre */
0x61, 0x74, 0x65, 0x53, 0x74, 0x72, 0x69, 0x6e, /* ateStrin */
0x67, 0x4c, 0x69, 0x73, 0x74, 0x28, 0x61, 0x4a, /* gList(aJ */
0x43, 0x61, 0x73, 0x2c, 0x20, 0x63, 0x6f, 0x6e, /* Cas, con */
0x63, 0x65, 0x70, 0x74, 0x4c, 0x69, 0x73, 0x74, /* ceptList */
0x29, 0x29, 0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, /* ));.     */
0x20, 0x20, 0x2f, 0x2f, 0x63, 0x6f, 0x6e, 0x63, /*   //conc */
0x65, 0x70, 0x74, 0x54, 0x79, 0x70, 0x65, 0x53, /* eptTypeS */
0x79, 0x73, 0x2e, 0x73, 0x65, 0x74, 0x4d, 0x65, /* ys.setMe */
0x6e, 0x74, 0x69, 0x6f, 0x6e, 0x73, 0x28, 0x55, /* ntions(U */
0x74, 0x69, 0x6c, 0x73, 0x2e, 0x66, 0x72, 0x6f, /* tils.fro */
0x6d, 0x43, 0x6f, 0x6c, 0x6c, 0x65, 0x63, 0x74, /* mCollect */
0x69, 0x6f, 0x6e, 0x54, 0x6f, 0x46, 0x53, 0x4c, /* ionToFSL */
0x69, 0x73, 0x74, 0x28, 0x61, 0x4a, 0x43, 0x61, /* ist(aJCa */
0x73, 0x2c, 0x20, 0x28, 0x43, 0x6f, 0x6c, 0x6c, /* s, (Coll */
0x65, 0x63, 0x74, 0x69, 0x6f, 0x6e, 0x29, 0x20, /* ection)  */
0x63, 0x6f, 0x6e, 0x66, 0x69, 0x64, 0x65, 0x6e, /* confiden */
0x63, 0x65, 0x4c, 0x69, 0x73, 0x74, 0x29, 0x29, /* ceList)) */
0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, /* ;.       */
0x63, 0x6f, 0x6e, 0x63, 0x65, 0x70, 0x74, 0x54, /* conceptT */
0x79, 0x70, 0x65, 0x53, 0x79, 0x73, 0x2e, 0x61, /* ypeSys.a */
0x64, 0x64, 0x54, 0x6f, 0x49, 0x6e, 0x64, 0x65, /* ddToInde */
0x78, 0x65, 0x73, 0x28, 0x61, 0x4a, 0x43, 0x61, /* xes(aJCa */
0x73, 0x29, 0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, /* s);.     */
0x20, 0x20, 0x2f, 0x2f, 0x20, 0x54, 0x72, 0x69, /*   // Tri */
0x70, 0x6c, 0x65, 0x73, 0x0a, 0x20, 0x20, 0x20, /* ples.    */
0x20, 0x20, 0x20, 0x4c, 0x69, 0x6e, 0x6b, 0x65, /*    Linke */
0x64, 0x4c, 0x69, 0x66, 0x65, 0x44, 0x61, 0x74, /* dLifeDat */
0x61, 0x53, 0x65, 0x72, 0x76, 0x69, 0x63, 0x65, /* aService */
0x52, 0x65, 0x73, 0x70, 0x6f, 0x6e, 0x73, 0x65, /* Response */
0x2e, 0x52, 0x65, 0x73, 0x75, 0x6c, 0x74, 0x20, /* .Result  */
0x6c, 0x69, 0x6e, 0x6b, 0x65, 0x64, 0x4c, 0x69, /* linkedLi */
0x66, 0x65, 0x44, 0x61, 0x74, 0x61, 0x52, 0x65, /* feDataRe */
0x73, 0x75, 0x6c, 0x74, 0x20, 0x3d, 0x20, 0x73, /* sult = s */
0x65, 0x72, 0x76, 0x69, 0x63, 0x65, 0x0a, 0x20, /* ervice.  */
0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, /*          */
0x20, 0x20, 0x20, 0x20, 0x20, 0x2e, 0x66, 0x69, /*      .fi */
0x6e, 0x64, 0x4c, 0x69, 0x6e, 0x6b, 0x65, 0x64, /* ndLinked */
0x4c, 0x69, 0x66, 0x65, 0x44, 0x61, 0x74, 0x61, /* LifeData */
0x45, 0x6e, 0x74, 0x69, 0x74, 0x69, 0x65, 0x73, /* Entities */
0x50, 0x61, 0x67, 0x65, 0x64, 0x28, 0x74, 0x65, /* Paged(te */
0x78, 0x74, 0x2c, 0x20, 0x30, 0x29, 0x3b, 0x0a, /* xt, 0);. */
0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x2f, 0x2f, /*       // */
0x20, 0x53, 0x79, 0x73, 0x74, 0x65, 0x6d, 0x2e, /*  System. */
```

```
0x6f, 0x75, 0x74, 0x2e, 0x70, 0x72, 0x69, 0x6e, /* out.prin */
0x74, 0x6c, 0x6e, 0x28, 0x22, 0x4c, 0x69, 0x6e, /* tln("Lin */
0x6b, 0x65, 0x64, 0x4c, 0x69, 0x66, 0x65, 0x44, /* kedLifeD */
0x61, 0x74, 0x61, 0x3a, 0x20, 0x22, 0x20, 0x2b, /* ata: " + */
0x20, 0x6c, 0x69, 0x6e, 0x6b, 0x65, 0x64, 0x4c, /*  linkedL */
0x69, 0x66, 0x65, 0x44, 0x61, 0x74, 0x61, 0x52, /* ifeDataR */
0x65, 0x73, 0x75, 0x6c, 0x74, 0x2e, 0x67, 0x65, /* esult.ge */
0x74, 0x45, 0x6e, 0x74, 0x69, 0x74, 0x69, 0x65, /* tEntitie */
0x73, 0x28, 0x29, 0x2e, 0x73, 0x69, 0x7a, 0x65, /* s().size */
0x28, 0x29, 0x29, 0x3b, 0x0a, 0x20, 0x20, 0x20, /* ());.    */
0x20, 0x20, 0x20, 0x66, 0x6f, 0x72, 0x20, 0x28, /*    for ( */
0x4c, 0x69, 0x6e, 0x6b, 0x65, 0x64, 0x4c, 0x69, /* LinkedLi */
0x66, 0x65, 0x44, 0x61, 0x74, 0x61, 0x53, 0x65, /* feDataSe */
0x72, 0x76, 0x69, 0x63, 0x65, 0x52, 0x65, 0x73, /* rviceRes */
0x70, 0x6f, 0x6e, 0x73, 0x65, 0x2e, 0x45, 0x6e, /* ponse.En */
0x74, 0x69, 0x74, 0x79, 0x20, 0x65, 0x6e, 0x74, /* tity ent */
0x69, 0x74, 0x79, 0x20, 0x3a, 0x20, 0x6c, 0x69, /* ity : li */
0x6e, 0x6b, 0x65, 0x64, 0x4c, 0x69, 0x66, 0x65, /* nkedLife */
0x44, 0x61, 0x74, 0x61, 0x52, 0x65, 0x73, 0x75, /* DataResu */
0x6c, 0x74, 0x2e, 0x67, 0x65, 0x74, 0x45, 0x6e, /* lt.getEn */
0x74, 0x69, 0x74, 0x69, 0x65, 0x73, 0x28, 0x29, /* tities() */
0x29, 0x20, 0x7b, 0x0a, 0x20, 0x20, 0x20, 0x20, /* ) {.     */
0x20, 0x20, 0x20, 0x20, 0x2f, 0x2f, 0x20, 0x53, /*     // S */
0x79, 0x73, 0x74, 0x65, 0x6d, 0x2e, 0x6f, 0x75, /* ystem.ou */
0x74, 0x2e, 0x70, 0x72, 0x69, 0x6e, 0x74, 0x6c, /* t.printl */
0x6e, 0x28, 0x22, 0x20, 0x3e, 0x20, 0x22, 0x20, /* n(" > "  */
0x2b, 0x20, 0x65, 0x6e, 0x74, 0x69, 0x74, 0x79, /* + entity */
0x2e, 0x67, 0x65, 0x74, 0x45, 0x6e, 0x74, 0x69, /* .getEnti */
0x74, 0x79, 0x28, 0x29, 0x29, 0x3b, 0x0a, 0x20, /* ty());.  */
0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x66, /*        f */
0x6f, 0x72, 0x20, 0x28, 0x4c, 0x69, 0x6e, 0x6b, /* or (Link */
0x65, 0x64, 0x4c, 0x69, 0x66, 0x65, 0x44, 0x61, /* edLifeDa */
0x74, 0x61, 0x53, 0x65, 0x72, 0x76, 0x69, 0x63, /* taServic */
0x65, 0x52, 0x65, 0x73, 0x70, 0x6f, 0x6e, 0x73, /* eRespons */
0x65, 0x2e, 0x52, 0x65, 0x6c, 0x61, 0x74, 0x69, /* e.Relati */
0x6f, 0x6e, 0x20, 0x72, 0x65, 0x6c, 0x61, 0x74, /* on relat */
0x69, 0x6f, 0x6e, 0x20, 0x3a, 0x20, 0x65, 0x6e, /* ion : en */
0x74, 0x69, 0x74, 0x79, 0x2e, 0x67, 0x65, 0x74, /* tity.get */
0x52, 0x65, 0x6c, 0x61, 0x74, 0x69, 0x6f, 0x6e, /* Relation */
0x73, 0x28, 0x29, 0x29, 0x20, 0x7b, 0x0a, 0x20, /* s()) {.  */
0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, /*          */
0x20, 0x74, 0x72, 0x69, 0x70, 0x6c, 0x65, 0x54, /*  tripleT */
0x79, 0x70, 0x65, 0x53, 0x79, 0x73, 0x20, 0x3d, /* ypeSys = */
0x20, 0x6e, 0x65, 0x77, 0x20, 0x54, 0x72, 0x69, /*  new Tri */
0x70, 0x6c, 0x65, 0x28, 0x61, 0x4a, 0x43, 0x61, /* ple(aJCa */
0x73, 0x29, 0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, /* s);.     */
0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x74, 0x72, /*       tr */
0x69, 0x70, 0x6c, 0x65, 0x54, 0x79, 0x70, 0x65, /* ipleType */
0x53, 0x79, 0x73, 0x2e, 0x73, 0x65, 0x74, 0x4f, /* Sys.setO */
0x62, 0x6a, 0x65, 0x63, 0x74, 0x28, 0x72, 0x65, /* bject(re */
```

```
0x6c, 0x61, 0x74, 0x69, 0x6f, 0x6e, 0x2e, 0x67, /* lation.g */
0x65, 0x74, 0x4f, 0x62, 0x6a, 0x28, 0x29, 0x29, /* etObj()) */
0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, /* ;.       */
0x20, 0x20, 0x20, 0x20, 0x74, 0x72, 0x69, 0x70, /*     trip */
0x6c, 0x65, 0x54, 0x79, 0x70, 0x65, 0x53, 0x79, /* leTypeSy */
0x73, 0x2e, 0x73, 0x65, 0x74, 0x53, 0x75, 0x62, /* s.setSub */
0x6a, 0x65, 0x63, 0x74, 0x28, 0x72, 0x65, 0x6c, /* ject(rel */
0x61, 0x74, 0x69, 0x6f, 0x6e, 0x2e, 0x67, 0x65, /* ation.ge */
0x74, 0x53, 0x75, 0x62, 0x6a, 0x28, 0x29, 0x29, /* tSubj()) */
0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, /* ;.       */
0x20, 0x20, 0x20, 0x20, 0x74, 0x72, 0x69, 0x70, /*     trip */
0x6c, 0x65, 0x54, 0x79, 0x70, 0x65, 0x53, 0x79, /* leTypeSy */
0x73, 0x2e, 0x73, 0x65, 0x74, 0x50, 0x72, 0x65, /* s.setPre */
0x64, 0x69, 0x63, 0x61, 0x74, 0x65, 0x28, 0x72, /* dicate(r */
0x65, 0x6c, 0x61, 0x74, 0x69, 0x6f, 0x6e, 0x2e, /* elation. */
0x67, 0x65, 0x74, 0x50, 0x72, 0x65, 0x64, 0x28, /* getPred( */
0x29, 0x29, 0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, /* ));.     */
0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x74, 0x72, /*       tr */
0x69, 0x70, 0x6c, 0x65, 0x54, 0x79, 0x70, 0x65, /* ipleType */
0x53, 0x79, 0x73, 0x2e, 0x61, 0x64, 0x64, 0x54, /* Sys.addT */
0x6f, 0x49, 0x6e, 0x64, 0x65, 0x78, 0x65, 0x73, /* oIndexes */
0x28, 0x61, 0x4a, 0x43, 0x61, 0x73, 0x29, 0x3b, /* (aJCas); */
0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, /* .        */
0x20, 0x7d, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, /*  }.      */
0x20, 0x7d, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, /*  }.      */
0x20, 0x50, 0x75, 0x62, 0x4d, 0x65, 0x64, 0x53, /*  PubMedS */
0x65, 0x61, 0x72, 0x63, 0x68, 0x53, 0x65, 0x72, /* earchSer */
0x76, 0x69, 0x63, 0x65, 0x52, 0x65, 0x73, 0x70, /* viceResp */
0x6f, 0x6e, 0x73, 0x65, 0x2e, 0x52, 0x65, 0x73, /* onse.Res */
0x75, 0x6c, 0x74, 0x20, 0x70, 0x75, 0x62, 0x6d, /* ult pubm */
0x65, 0x64, 0x52, 0x65, 0x73, 0x75, 0x6c, 0x74, /* edResult */
0x20, 0x3d, 0x20, 0x73, 0x65, 0x72, 0x76, 0x69, /*  = servi */
0x63, 0x65, 0x2e, 0x66, 0x69, 0x6e, 0x64, 0x50, /* ce.findP */
0x75, 0x62, 0x4d, 0x65, 0x64, 0x43, 0x69, 0x74, /* ubMedCit */
0x61, 0x74, 0x69, 0x6f, 0x6e, 0x73, 0x28, 0x74, /* ations(t */
0x65, 0x78, 0x74, 0x2c, 0x20, 0x30, 0x29, 0x3b, /* ext, 0); */
0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x4c, /* .      L */
0x69, 0x73, 0x74, 0x3c, 0x44, 0x6f, 0x63, 0x75, /* ist<Docu */
0x6d, 0x65, 0x6e, 0x74, 0x3e, 0x20, 0x64, 0x6f, /* ment> do */
0x63, 0x4c, 0x69, 0x73, 0x74, 0x20, 0x3d, 0x20, /* cList =  */
0x70, 0x75, 0x62, 0x6d, 0x65, 0x64, 0x52, 0x65, /* pubmedRe */
0x73, 0x75, 0x6c, 0x74, 0x2e, 0x67, 0x65, 0x74, /* sult.get */
0x44, 0x6f, 0x63, 0x75, 0x6d, 0x65, 0x6e, 0x74, /* Document */
0x73, 0x28, 0x29, 0x3b, 0x0a, 0x20, 0x20, 0x20, /* s();.    */
0x20, 0x20, 0x20, 0x2f, 0x2f, 0x20, 0x53, 0x74, /*    // St */
0x72, 0x69, 0x6e, 0x67, 0x5b, 0x5d, 0x20, 0x70, /* ring[] p */
0x6d, 0x69, 0x64, 0x73, 0x20, 0x3d, 0x20, 0x6e, /* mids = n */
0x65, 0x77, 0x20, 0x53, 0x74, 0x72, 0x69, 0x6e, /* ew Strin */
0x67, 0x5b, 0x64, 0x6f, 0x63, 0x4c, 0x69, 0x73, /* g[docLis */
0x74, 0x2e, 0x73, 0x69, 0x7a, 0x65, 0x28, 0x29, /* t.size() */
```

```
0x5d, 0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, /* ];.      */
0x20, 0x2f, 0x2f, 0x20, 0x69, 0x6e, 0x74, 0x20, /*  // int  */
0x69, 0x20, 0x3d, 0x20, 0x30, 0x3b, 0x0a, 0x20, /* i = 0;.  */
0x20, 0x20, 0x20, 0x20, 0x20, 0x66, 0x6f, 0x72, /*      for */
0x20, 0x28, 0x44, 0x6f, 0x63, 0x75, 0x6d, 0x65, /*  (Docume */
0x6e, 0x74, 0x20, 0x64, 0x6f, 0x63, 0x20, 0x3a, /* nt doc : */
0x20, 0x64, 0x6f, 0x63, 0x4c, 0x69, 0x73, 0x74, /*  docList */
0x29, 0x20, 0x7b, 0x0a, 0x20, 0x20, 0x20, 0x20, /* ) {.     */
0x20, 0x20, 0x20, 0x20, 0x64, 0x6f, 0x63, 0x75, /*     docu */
0x6d, 0x65, 0x6e, 0x74, 0x54, 0x79, 0x70, 0x65, /* mentType */
0x53, 0x79, 0x73, 0x20, 0x3d, 0x20, 0x6e, 0x65, /* Sys = ne */
0x77, 0x20, 0x65, 0x64, 0x75, 0x2e, 0x63, 0x6d, /* w edu.cm */
0x75, 0x2e, 0x6c, 0x74, 0x69, 0x2e, 0x6f, 0x61, /* u.lti.oa */
0x71, 0x61, 0x2e, 0x74, 0x79, 0x70, 0x65, 0x2e, /* qa.type. */
0x72, 0x65, 0x74, 0x72, 0x69, 0x65, 0x76, 0x61, /* retrieva */
0x6c, 0x2e, 0x44, 0x6f, 0x63, 0x75, 0x6d, 0x65, /* l.Docume */
0x6e, 0x74, 0x28, 0x61, 0x4a, 0x43, 0x61, 0x73, /* nt(aJCas */
0x29, 0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, /* );.      */
0x20, 0x20, 0x20, 0x64, 0x6f, 0x63, 0x75, 0x6d, /*    docum */
0x65, 0x6e, 0x74, 0x54, 0x79, 0x70, 0x65, 0x53, /* entTypeS */
0x79, 0x73, 0x2e, 0x73, 0x65, 0x74, 0x54, 0x69, /* ys.setTi */
0x74, 0x6c, 0x65, 0x28, 0x22, 0x68, 0x74, 0x74, /* tle("htt */
0x70, 0x3a, 0x2f, 0x2f, 0x77, 0x77, 0x77, 0x2e, /* p://www. */
0x6e, 0x63, 0x62, 0x69, 0x2e, 0x6e, 0x6c, 0x6d, /* ncbi.nlm */
0x2e, 0x6e, 0x69, 0x68, 0x2e, 0x67, 0x6f, 0x76, /* .nih.gov */
0x2f, 0x70, 0x75, 0x62, 0x6d, 0x65, 0x64, 0x2f, /* /pubmed/ */
0x22, 0x20, 0x2b, 0x20, 0x64, 0x6f, 0x63, 0x2e, /* " + doc. */
0x67, 0x65, 0x74, 0x50, 0x6d, 0x69, 0x64, 0x28, /* getPmid( */
0x29, 0x29, 0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, /* ));.     */
0x20, 0x20, 0x20, 0x20, 0x64, 0x6f, 0x63, 0x75, /*     docu */
0x6d, 0x65, 0x6e, 0x74, 0x54, 0x79, 0x70, 0x65, /* mentType */
0x53, 0x79, 0x73, 0x2e, 0x73, 0x65, 0x74, 0x44, /* Sys.setD */
0x6f, 0x63, 0x49, 0x64, 0x28, 0x64, 0x6f, 0x63, /* ocId(doc */
0x2e, 0x67, 0x65, 0x74, 0x50, 0x6d, 0x69, 0x64, /* .getPmid */
0x28, 0x29, 0x29, 0x3b, 0x0a, 0x20, 0x20, 0x20, /* ());.    */
0x20, 0x20, 0x20, 0x20, 0x20, 0x64, 0x6f, 0x63, /*      doc */
0x75, 0x6d, 0x65, 0x6e, 0x74, 0x54, 0x79, 0x70, /* umentTyp */
0x65, 0x53, 0x79, 0x73, 0x2e, 0x61, 0x64, 0x64, /* eSys.add */
0x54, 0x6f, 0x49, 0x6e, 0x64, 0x65, 0x78, 0x65, /* ToIndexe */
0x73, 0x28, 0x61, 0x4a, 0x43, 0x61, 0x73, 0x29, /* s(aJCas) */
0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, /* ;.       */
0x20, 0x20, 0x2f, 0x2f, 0x20, 0x64, 0x6f, 0x63, /*   // doc */
0x75, 0x6d, 0x65, 0x6e, 0x74, 0x54, 0x79, 0x70, /* umentTyp */
0x65, 0x53, 0x79, 0x73, 0x2e, 0x73, 0x65, 0x74, /* eSys.set */
0x44, 0x6f, 0x63, 0x49, 0x64, 0x28, 0x64, 0x6f, /* DocId(do */
0x63, 0x29, 0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, /* c);.     */
0x20, 0x20, 0x20, 0x20, 0x2f, 0x2f, 0x20, 0x70, /*     // p */
0x6d, 0x69, 0x64, 0x73, 0x5b, 0x69, 0x2b, 0x2b, /* mids[i++ */
0x5d, 0x20, 0x3d, 0x20, 0x22, 0x68, 0x74, 0x74, /* ] = "htt */
0x70, 0x3a, 0x2f, 0x2f, 0x77, 0x77, 0x77, 0x2e, /* p://www. */
```

```
0x6e, 0x63, 0x62, 0x69, 0x2e, 0x6e, 0x6c, 0x6d, /* ncbi.nlm */
0x2e, 0x6e, 0x69, 0x68, 0x2e, 0x67, 0x6f, 0x76, /* .nih.gov */
0x2f, 0x70, 0x75, 0x62, 0x6d, 0x65, 0x64, 0x2f, /* /pubmed/ */
0x22, 0x20, 0x2b, 0x20, 0x64, 0x6f, 0x63, 0x2e, /* " + doc. */
0x67, 0x65, 0x74, 0x50, 0x6d, 0x69, 0x64, 0x28, /* getPmid( */
0x29, 0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, /* );.      */
0x20, 0x20, 0x20, 0x2f, 0x2f, 0x20, 0x53, 0x79, /*    // Sy */
0x73, 0x74, 0x65, 0x6d, 0x2e, 0x6f, 0x75, 0x74, /* stem.out */
0x2e, 0x70, 0x72, 0x69, 0x6e, 0x74, 0x6c, 0x6e, /* .println */
0x28, 0x20, 0x70, 0x6d, 0x69, 0x64, 0x73, 0x5b, /* ( pmids[ */
0x69, 0x20, 0x2d, 0x20, 0x31, 0x5d, 0x29, 0x3b, /* i - 1]); */
0x0a, 0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x7d, /* .      } */
0x0a, 0x20, 0x20, 0x20, 0x20, 0x7d, 0x20, 0x63, /* .    } c */
0x61, 0x74, 0x63, 0x68, 0x20, 0x28, 0x49, 0x4f, /* atch (IO */
0x45, 0x78, 0x63, 0x65, 0x70, 0x74, 0x69, 0x6f, /* Exceptio */
0x6e, 0x20, 0x65, 0x29, 0x20, 0x7b, 0x0a, 0x20, /* n e) {.  */
0x20, 0x20, 0x20, 0x20, 0x20, 0x2f, 0x2f, 0x20, /*      //  */
0x54, 0x4f, 0x44, 0x4f, 0x20, 0x41, 0x75, 0x74, /* TODO Aut */
0x6f, 0x2d, 0x67, 0x65, 0x6e, 0x65, 0x72, 0x61, /* o-genera */
0x74, 0x65, 0x64, 0x20, 0x63, 0x61, 0x74, 0x63, /* ted catc */
0x68, 0x20, 0x62, 0x6c, 0x6f, 0x63, 0x6b, 0x0a, /* h block. */
0x20, 0x20, 0x20, 0x20, 0x20, 0x20, 0x65, 0x2e, /*       e. */
0x70, 0x72, 0x69, 0x6e, 0x74, 0x53, 0x74, 0x61, /* printSta */
0x63, 0x6b, 0x54, 0x72, 0x61, 0x63, 0x65, 0x28, /* ckTrace( */
0x29, 0x3b, 0x0a, 0x20, 0x20, 0x20, 0x20, 0x7d, /* );.    } */
0x0a, 0x20, 0x20, 0x7d, 0x0a, 0x7d, 0x0a        /* .  }.}. */
};
```

———-

Bibliography

[1] Cisco
"Data Leakage Worldwide: The High Cost of Insider Threats" (2008)
http://www.cicco.com/c/en/us/solutions/collateral/enterprise-networks/data-loss-prevention/white_paper_c11-506224.html

[2] Cisco
"Data Leakage Worldwide: Common Risks and Mistakes Employees Make" (2008)
http://www.cisco.com/c/en/us/solutions/collateral/enterprise-networks/data-loss-prevention/white_paper_c11-499060.html

[3] Cisco
"Data Leakage Worldwide: The Effectiveness of Security Policies" (2008)
http://www.cisco.com/c/en/us/solutions/collateral/enterprise-networks/data-loss-prevention/white_paper_c11-503131.html

[4] "FPGA 101 - Making awesome stuff with FPGAs [30c3]"
www.youtube.com/watch?v=Er9luiBa32k

[5] "Hello World on your FPGA" www.youtube.com/watch?v=gBknFw511s0

[6] Khalilzad, Nima Moghaddami; Pourshakour, Sheida
"FPGA implementation of Real-time Ethernet communication using RMII Interface"
EXFILT\FPGA-RealTimeEthernet.pdf

[7] BOSE
adsoftheworld.com/sites/default/files/styles/media_retina/public/images/bose_3.jpg?itok=WxDfXs76

[8] Microchip.com
"Ethernet Physical Layer"
http://ww1.microchip.com/downloads/en/AppNotes/01120a.pdf

[9] Teknixx.com
"Some Linux Iptables Examples"
teknixx.com/some-linux-iptables-examples

[10] Forouzan, B.A. (2000).
"TCP/IP: Protocol Suite (1st ed.)"
New Delhi, India: Tata McGraw-Hill Publishing Company Limited.

[11] Slacksite.com
"Active FTP vs. Passive FTP, a Definitive Explanation"
Archived from the original on 2014-12-31.

[12] Parker, Don
"Understanding the FTP Protocol"
September 2005. Windowsnetworking.com.

[13] Postel, J. and Reynolds, J.
"RFC 959 (Standard) File Transfer Protocol (FTP)"
(October 1985).

[14] Allman, M. and Metz, C. and Ostermann, S.
"RFC 2428 (Proposed Standard) Extensions for IPv6, NAT, and Extended Passive Mode."
(September 1998).

[15] Putnam, Andrew et al.
"A Reconfigurable Fabric or Accelerating Large-Scale Datacenter Services"
41st Ann. ISCA, June 2014
http://research.microsoft.com/apps/pubs/default.aspx?id=212001

[16] Kim, Joo-Young; Hauck, Scott; Burger, Doug
"A Scalable Multi-engine Xpress9 Compressor with Asynchronous Data Transfer"
IEEE 22nd Int. Symp on Field-Programmable Custom Computing Machines
http://research.microsoft.com/apps/pubs/default.aspx?id=217317

[17] Fowers, Jeremy; Kim, Joo-Young; Burger, Doug; Hauck, Scott
"A Scalable High-Bandwidth Architecture for Lossless Compression on FPGAs"
23rd IEEE Int.Symp. on Field-Programmable Custom Computing Machines. http://research.microsoft.com/pubs/245093/fccm2015_cr2.pdf

[18] Hormati, Amir; Kudlur, Manjunath; Rabbah, Rodric; Mahlke, Scott
"Optimus: Efficient realization of Streaming Applications on FPGAs"
2008 Int Conf on Compilers, Architecture, and Synthesis for Embedded Systems

[19] Video, Microsoft Channel 9
http://research.microsoft.com/apps/video/default.aspx?id=219486

[20] Ferro, Greg
"Why Firewalls Won't Matter In A Few Years"
http://etherealmind.com/why-firewalls-wont-matter-in-a-few-years

[21] Packet Capture Hardware
"InterStream 4322C Product Overview"
http://www.colfaxdirect.com/store/pc/catalog/is4322c.pdf

[22] NetFPGA
"NetFPGA Setup Guide"
https://github.com/NetFPGA/netfpga/wiki/Guide

[23] NetFPGA
"The NetFPGA source code"
http://github.com/NetFPGA/netfpga

[24] NetFPGA
"The NetFPGA 10G development board"
http://netfpga.org/site/#/systems/3netfpga-10g/details/

[25] Whelan, Timothy
"Hardware-Based Packet Filtering Using FPGAs"
http://www.cs.ru.ac.za/research/g07w1974/documents/thesis.pdf

[26] Pal, Rahul; Gotiya, Rahul; Singh, Pankaj; Agrawal, Amit
"Design of a Embedded Ethernet Packet Sniffer"
Int. J. of Innovative Technology and Exploring Engineering ISSN: 2278-3075 Vol 2 Issue 5 April 2013

[27] Salazar, Jayson; Schaefer, Rafael
"Penetration Testing in the Age of IPv6"
http://haxpo.nl/materials/haxpo2015ams/D3%20-%20R.%20Schaefer%20and%20J.%20Salazar%20-%20Pentesting%20in%20the%20Age%20of%20IPv6.pdf

[28] RFCs
"Request for Comments"
http://www.rfc-editor.org/search/standards.php

[29] Paar, Christof
"SHA-1 Hash Function"
https://www.youtube.com/watch?v=5q8q4PhN0cw

[30] Eastlake, D.; Jones, P.
"RFC 3174: US Secure Hash Function 1 (SHA1)"
https://tools.ietf.org/html/rfc3174

[31] Anonymous
"SHA1 Description"
http://www.cs.rit.edu/~bcw5910/482/TeamFlux.pdf

[32] CuriousInventor
"How Bitcoin Works Under The Hood"
https://www.youtube.com/watch?v=Lx9zgZCMqXE

[33] OpenFlow
www.opennetworkingfoundation.org

[34] NetFPGA 10G board
http://netfpga.org/10G_specs.html

[35] NetFPGA Packet Generator
https://github.com/NetFPGA/netfpga/wiki/PacketGenerator

[36] DE5 NetFPGA Packet Generator Users Guide
http://www.ecs.umass.edu/ece/tessier/rcg/netfpga-de5/download/DE5_Packet_Generator_User_Guide_v1.0.pdf

[37] Cornell
"Ethernet Communication Interface for the FPGA"
http://people.ece.cornell.edu/land/courses/ece5760/FinalProjects/f2011/mis47_ayg6/mis47_ayg6/

[38] Altera
"40G Base-KR4 Ethernet Hardware Demo"
http://www.alterawiki.com/wiki/40G_Base-KR4_Ethernet_Hardware_Demo

[39] Packer Sniffer
//en.wikipedia.org/wiki/Packet_analyzer

[40] Wireshark
"Sample Captures"
https://wiki.wireshark.org/SampleCaptures

[41] Wikipedia
"IPv4"
http://en.wikipedia.org/wiki/IPv4#Header

[42] RFC6864
"Updated Specification of the IPv4 ID Field"
http://tools.ietf.org/html/rfc6864

[43] Wikipedia
"List of IP protocol numbers"
http://en.wikipedia.org/wiki/List_of_IP_protocol_numbers

[44] Marsgod
"Secure Hash Algorithm (SHA-160)"
http://www.opencores.org/cores/sha_core/

[45] Majkowski, Marek
"How to receive a million packets per second"
https://blog.cloudflare.com/how-to-receive-a-million-packets/

[46] IEEE Computer Society
"802.3 Part 3: CSMA/CD access method and physical layer specification"
http://www.ece.gatech.edu/academic/courses/ece4006/fall2002/group7/802/00988967.pdf

[47] Micrel
"Ethernet PHY Data Sheet"
http://www.micrel.com/_PDF/Ethernet/datasheets/ksz9021rl-rn_ds.pdf

[48] Ford, A. et al.
"Architectural Guidelines for Multipath TCP Development"
RFC 6182 March 2011
http://www.potaroo.net/ispcol/2015-06/mptcp.html

[49] Ford, A. et al.
"TCP Extensions for Multipath Operation with Multiple Addresses"
RFC 6824 Jan 2013
http://www.potaroo.net/ispcol/2015-06/mptcp.html

[50] Knuth, Donald E.
"Literate Programming"
CSLI Lecture Notes, No. 27 ISBN 0-937073-80-6 (1992)

[51] NIST
"Recommendation for Random Number Generation Using Deterministic Random Bit Generators"
http://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-90Ar1.pdf

[52] CPNI
"Detecting and Deterring Data Exfiltration: Guide for Implementers"
http://www.cpni.gov.uk/Documents/Publications/2014/2014-04-25-de-mwr-technical-report.pdf

[53] CPNI
"Detecting and Deterring Data Exfiltration: Executive Overview"
http://www.cpni.gov.uk/Documents/Publications/2014/2014-04-25-de-mwr-executive-report.pdf

[54] Xilinx
"Vivado Design Tools"
http://www.xilinx.com/support/download.html

[55] Rambus
"Rambus CryptoManager Secure Feature Management Platform"
http://www.rambus.com/technology/item/979-rambus-cryptography-research-division-unveils-cryptomanager-secure-feature-management-platform

[56] Hackaday
"5 Dollar FPGA"
http://hackaday.com/project/6592-dipsy

[57] Zeltser, Lenny
"Tunneling Data and Commands Over DNS to Bypass Firewalls"
https://zeltser.com/c2-dns-tunneling

[58] fpga4fun.com
"10BASE-T FPGA interface IP/UDP over Ethernet"
www.fpga4fun.com/10BASE-T.html

[59] vivado1
https://www.youtube.com/watch?v=xEK6LJxPdS0

[60] vivado2
https://www.youtube.com/watch?v=i8axs4hw2f4

[61] vivado3
https://www.youtube.com/watch?v=PqWpg2kk2hY

[62] Bowman, James
"J1: a small Forth CPU Core for FPGAs"
http://excamera.com/files/j1.pdf
http://www.ros.org/wiki/wge100_camera_firmware https://hackaday.com/2010/12/01/j1-a-small-fast-cpu-core-for-fpga/ http://excamera.com/sphinx/fpga-j1.html

[63] domipheus
"Designing a CPU in VHDL"
http://labs.domipheus.com/blog/designing-a-cpu-in-vhdl-part-1-rationale-tools-meth

[64] Forth
"ANSI Forth Standard"
http://www.forth.org/svfig/Win32Forth/DPANS94.txt

[65] NIST
"SHA3-Standard: Permutation-Based Hash and Extendable-Output Functions"
http://nvlpubs.nist.gov/nistpubs/FIPS/NIST.FIPS.202.pdf

[66] Loeliger, R.G.
"Threaded Interpretive Languages"
Byte Books ISBN 0-07-038360-X

[67] Aguilar, Hugh
"ANS-Forth libraries"
http://papa.motd.org/cave/novice.4th/readme.txt

[68] Forth Committee
"Forth Standard 200x (2 November 2014)"
http://www.forth200x.org/documents/forth14-5.pdf

Index