Design and Optimization of Mobile Aggregation Architectures

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(Yanni)

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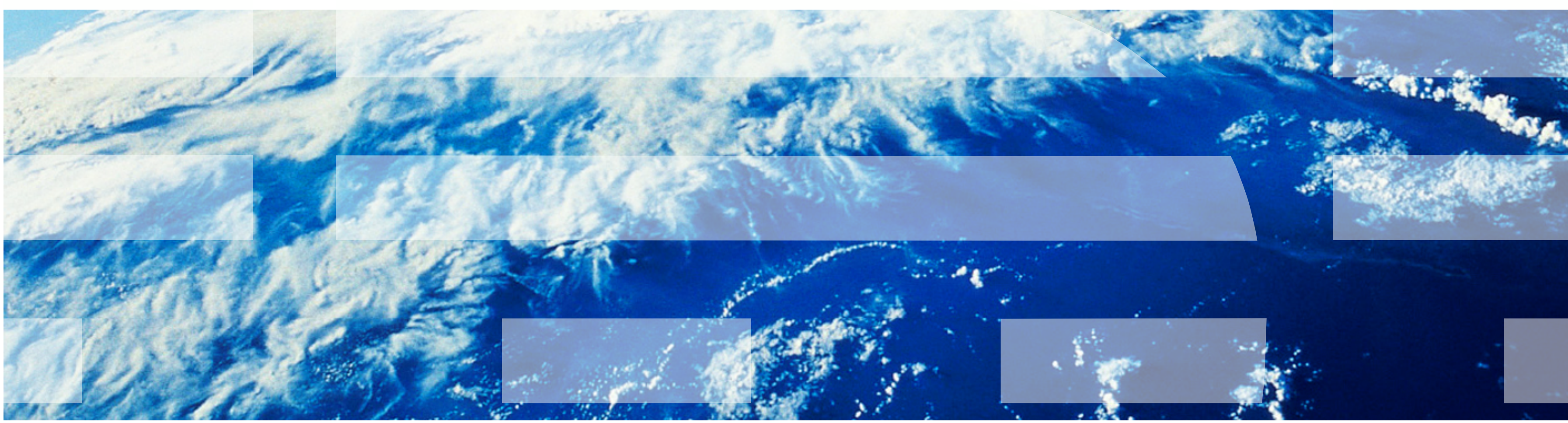


http://people.engr.ncsu.edu/ipapapa/Files/PurdueCIT.pdf

Who am I?

- Dual Major PhD in North Carolina State University
  - Computer Engineering
  - Operations Research
- IBM (3 years)
  - Emerging Technology Institute:
    - In house incubator team reporting directly to the CTO and VP
  - TJ Watson Research Center:
    - IT & Wireless convergence group
- NCSU (3 years RA & TA)
  - Taught Engineering, Networking and Simulation courses
  - Research funded by IBM, Cisco Systems, Time Warner Cable
- Appointments with
  - University of Patras
  - Technical Chamber of Greece
  - VTT Technical Institute in Finland
- Fellowships:
  - IBM PhD Fellow
  - Academy of Athens PhD Fellow

What I do

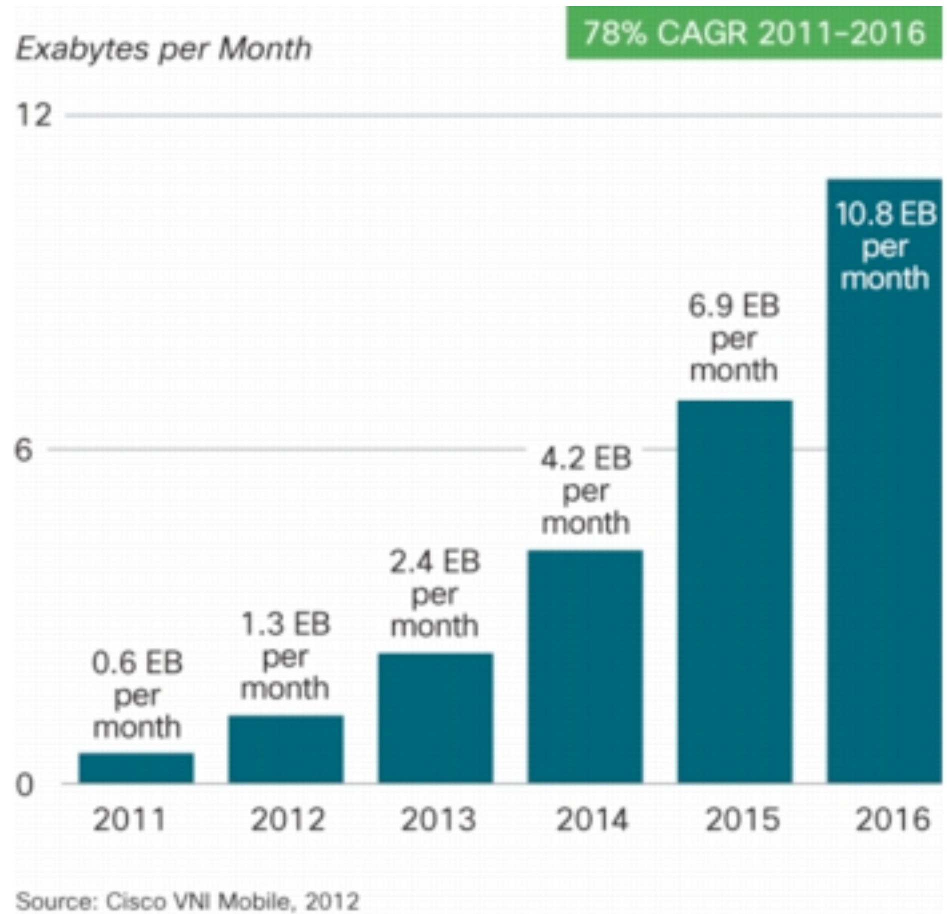
- Current work
  - Server side NoSQL/JSON solution for end-stores
  - Working with front-end caches and databases
- Research Interests:
  - Data analytics in wireless networks
  - Byte level deduplication
  - Performance analysis & simulations
  - Elasticity in Cloud Computing
- Experience with E-Learning technologies:
  - Synchronous (e.g. virtual meeting rooms) and Asynchronous (e.g. video recordings) types of assisting.
  - Emulation of computer networking labs through virtualization.
- Publication Record
  - 5 Peer-Reviewed journals
  - 12 Conference proceedings
  - 8 Submitted patents
  - 3 Book chapters
  - 121 Citations
- More info: http://people.engr.ncsu.edu/ipapapa

Motivation

Smartphones

+ =

Need For Speed

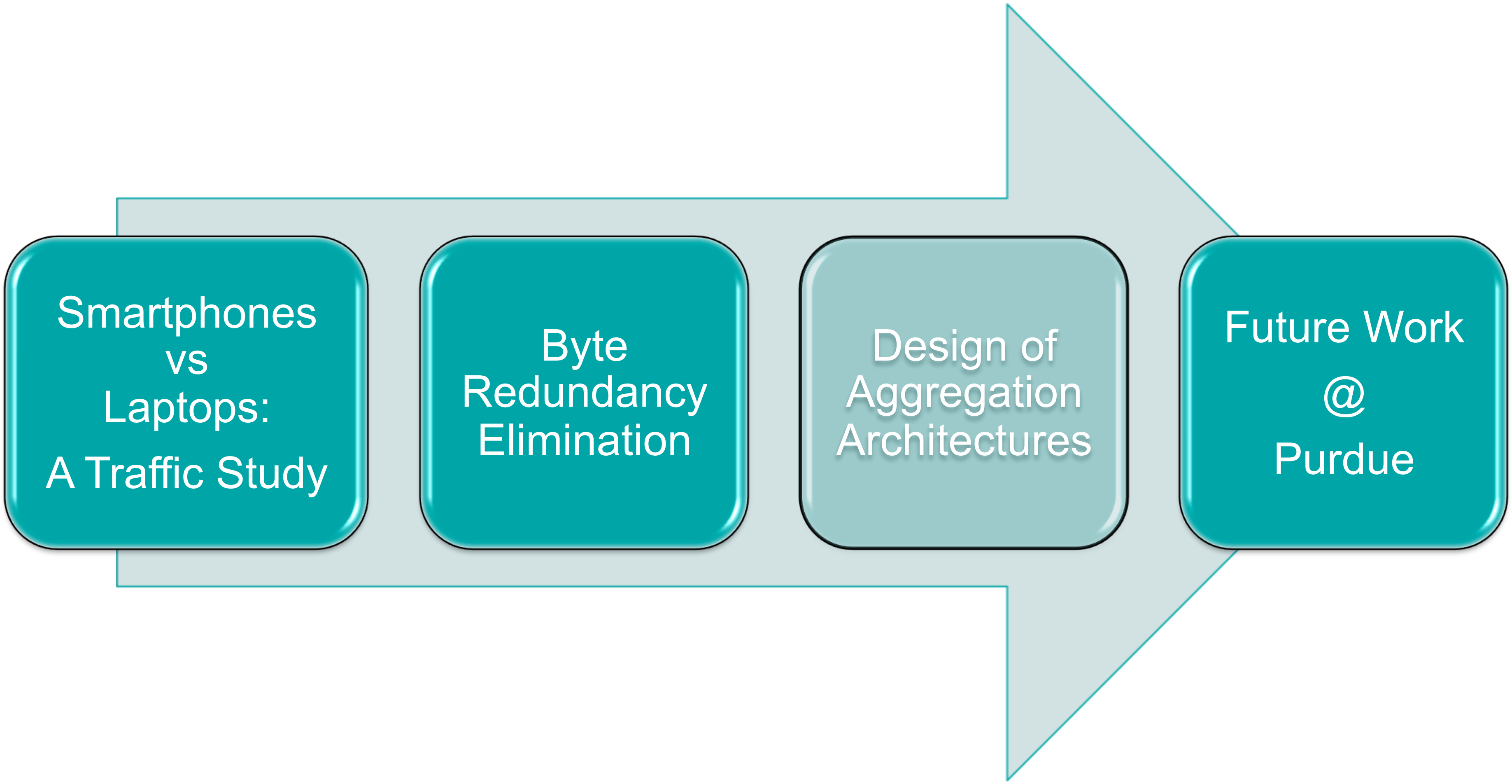


Wireless Service Providers have to transfer this traffic to the Internet!

Introduction

- Operating System fingerprinting algorithm based on data mining principles
  - Compared Smartphones vs Laptops.
- Analyzed IP lease traffic behavior
  - Proposed novel IP lease policy that improves address space utilization six-fold and without increasing the overhead.
- Analyzed Web traffic behavior and object caching
  - Demonstrated that a 10MB browser cache can save on average ~5%.
  - Showed the importance of storing policies in proxy caches.
- Designed a "Hybrid" Byte Redundancy Elimination
  - Provides more savings, with less memory space and is x3 faster.
  - Added QoS in redundancy elimination.

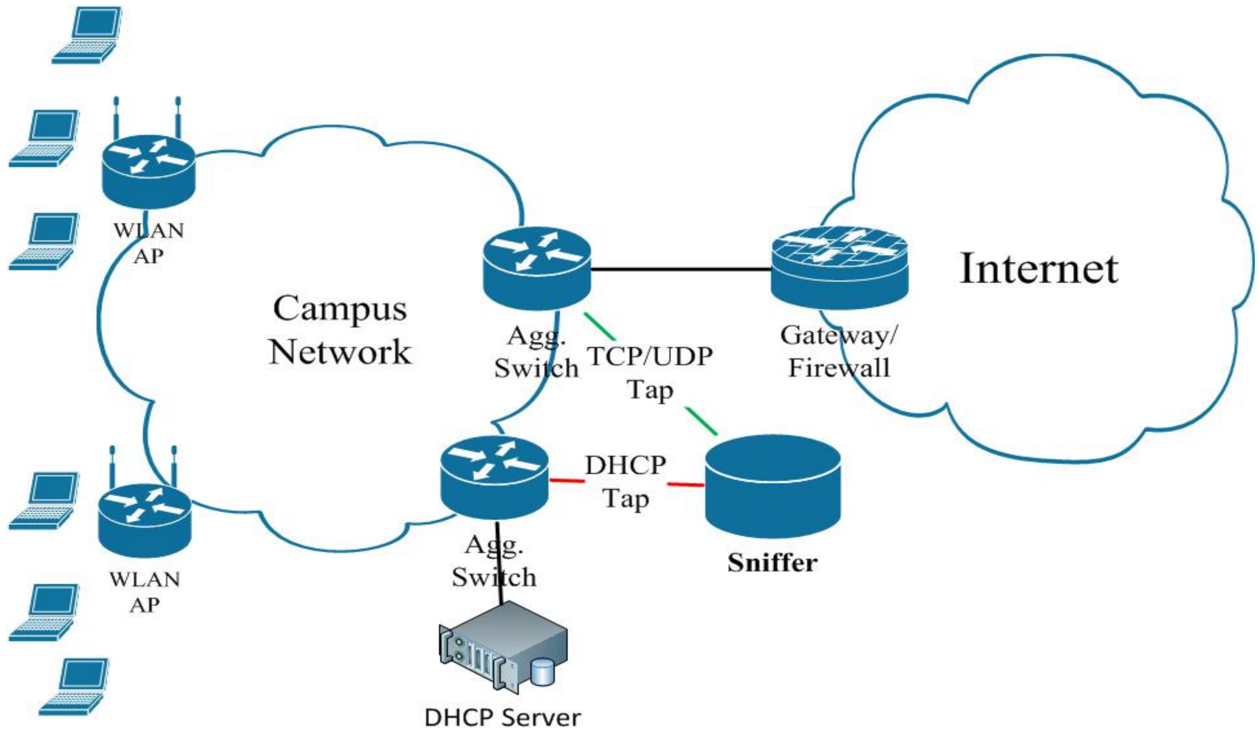
Presentation Outline



Section 1

Smartphones vs Laptops: A traffic study

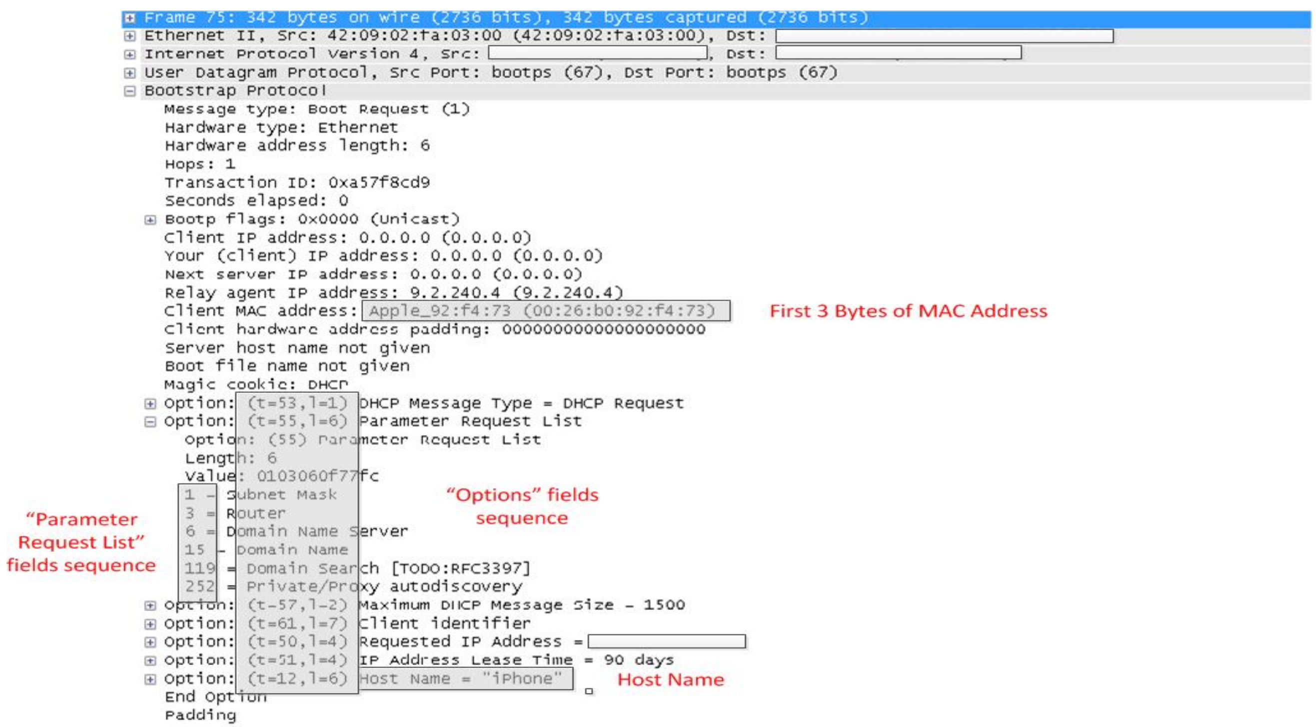
Trace Collection



Trace Type	IBM Research	NCSU Centennial
Dates (2012)	Feb 29 – Mar 25	Jan 15 – Feb 15
Client MAC address	2980	8726
Available IP address	4096 (8 * /23)	2048 (/21)
DHCP Leases	12h	15 min
TCP/UDP Bytes	2.5TB	4.9TB
Software Used	Hacked Bro IDS 2.0	

Device Identification

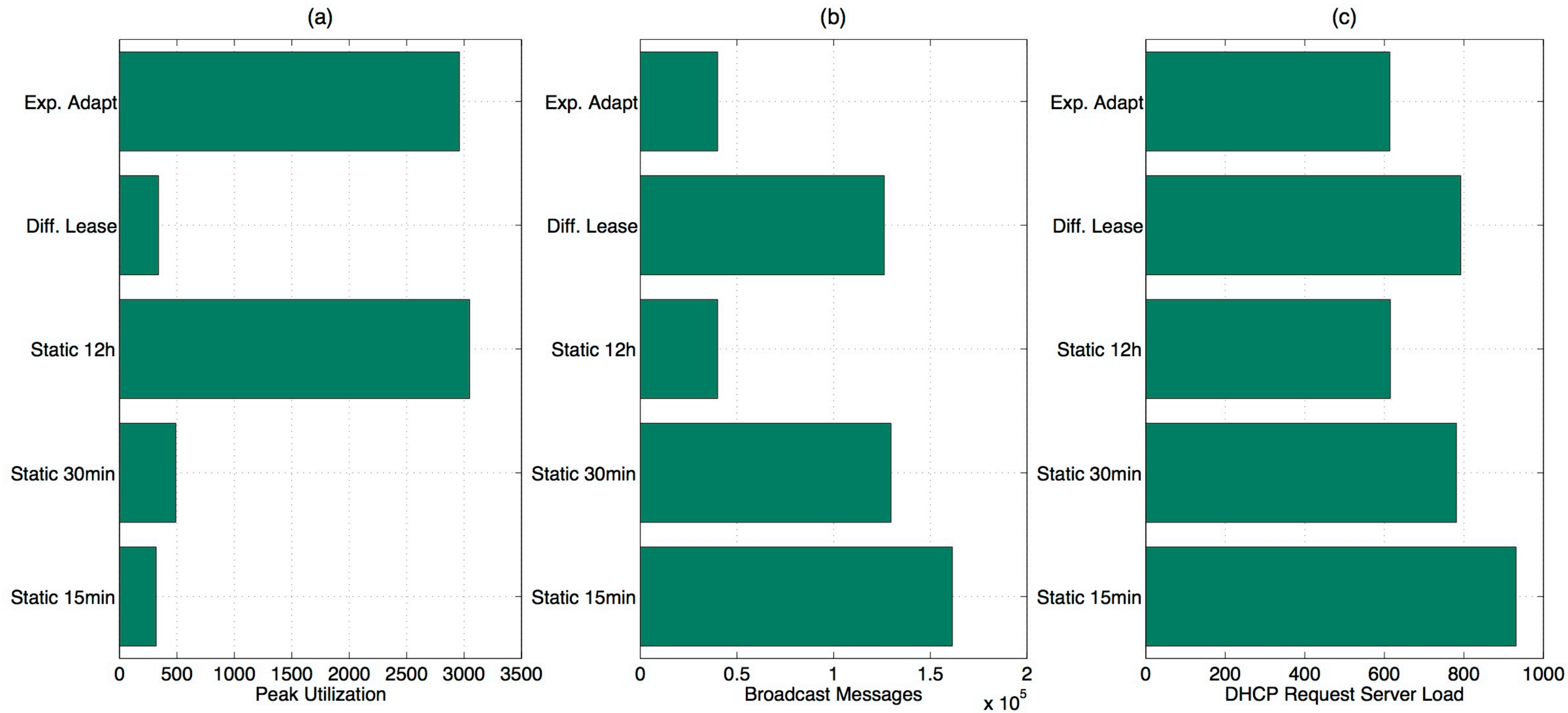
- We found correlation between the fields of the DHCP Request header and the OS
  1. *Host-Name*
  2. *Vendor-Name*
  3. *Parameter-Request-List*
  4. Organization Unique Identifier (OUI)
  5. *Options* parameter sequence
- Developed a **data mining algorithm** that quantifies the correlation



Classification Outcome

		IBM Research		NCSU Centennial	
Device	OS	#	%	#	%
Laptop	All	**2176**	**73.02**	**3970**	**45.50**
	Windows	1787	59.92	2819	32.31
	Mac OS X	385	12.92	1131	12.96
	Linux	4	0.13	20	0.23
Smartphone	All	**735**	**23.66**	**4489**	**51.44**
	iPhone/iPad/iPod	577	19.36	3069	35.17
	Android	126	4.24	1336	15.29
	BlackBerry	31	1.04	84	0.96
	Windows Mobile	1	0.03	2	0.02
Other	All	**69**	**2.32**	**267**	**3.06**
	Cisco VoIP	9	0.32	-	-
	Unidentified	60	2.01	267	3.06
All		2980	100	8726	100

DHCP Traffic: Differentiated Lease Policy

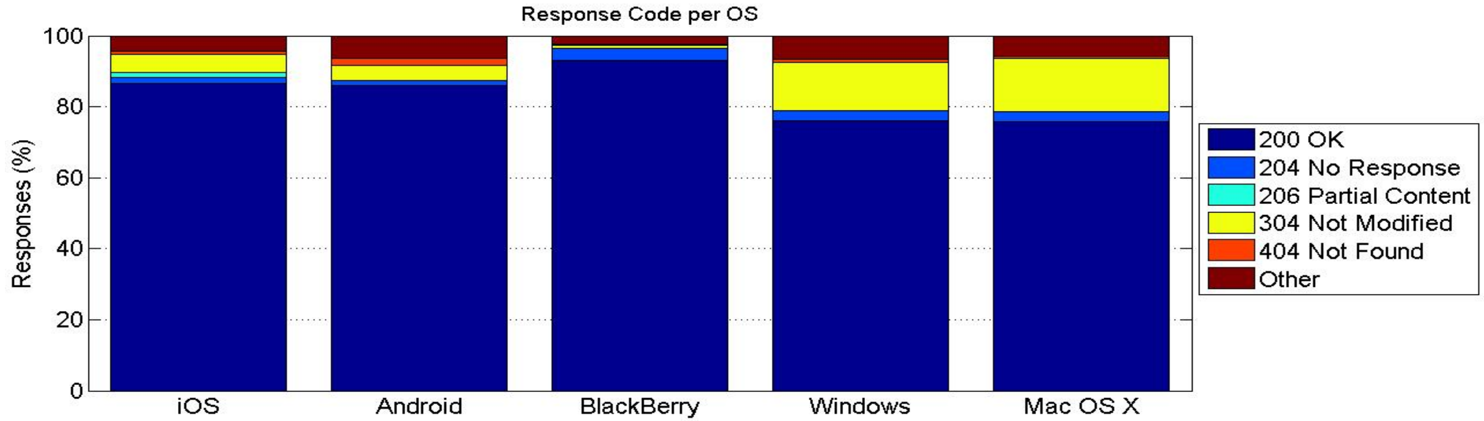


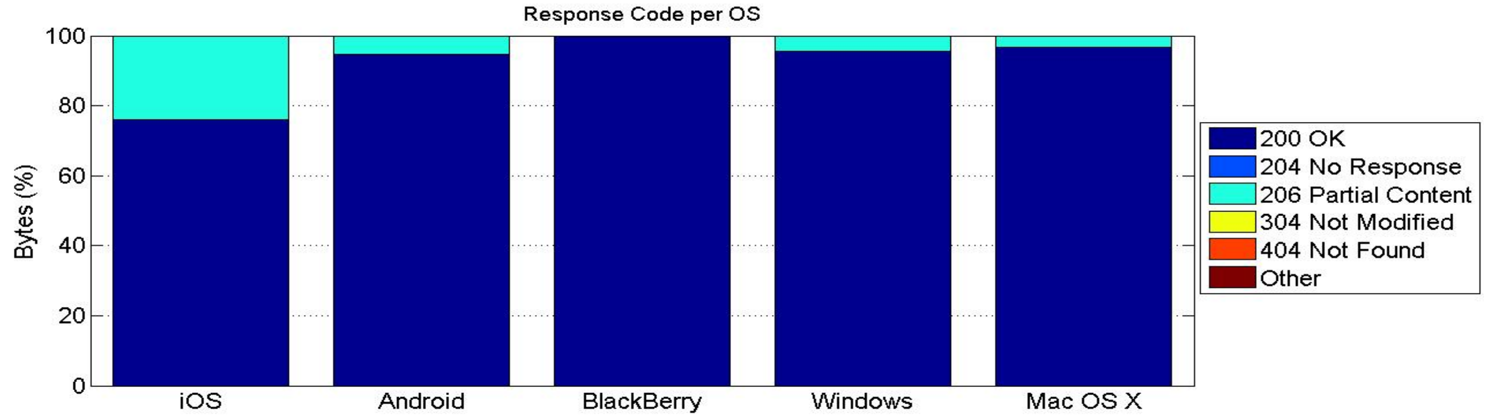
a) **Static Policies**: Fixed lease of 15 min, 30 min or 12h (most common case).

b) **Exponential Adaptation**: Allocates a short lease to client once it arrives, and doubles the lease time every time the client renews the lease.

c) **Differential Lease:** Takes advantage of the OS fingerprinting algorithm, and allocates different lease values to each device.
   – iOS 1000 secs, Android & BlackBerrys 2000 secs, Windows & Mac OS X = 4000 secs.

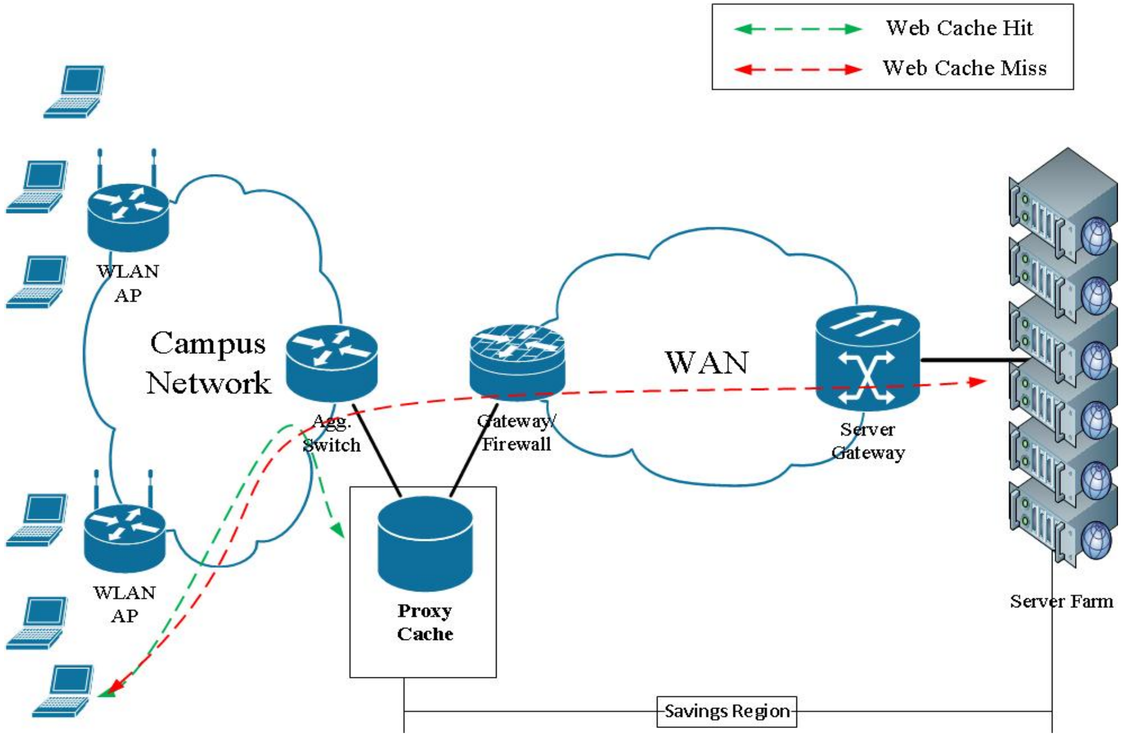
Web Traffic: Response Code





- An HTTP Response code indicates the "status" of the object in the server.
- **304 Not Modified:** validate the client's cached copy on the browser cache.
  - Windows and Mac OS X generate more than smartphones.
- **206 Partial Content:** used for large objects that must be chunked.
  - iOS generate way more than any other OS.

Web Traffic: Proxy Cache Advantages & Metrics

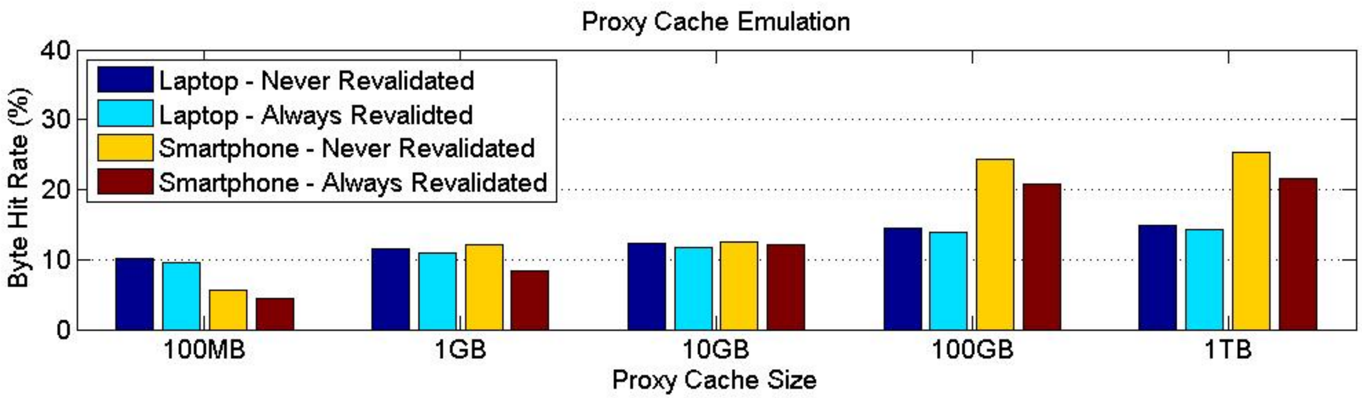


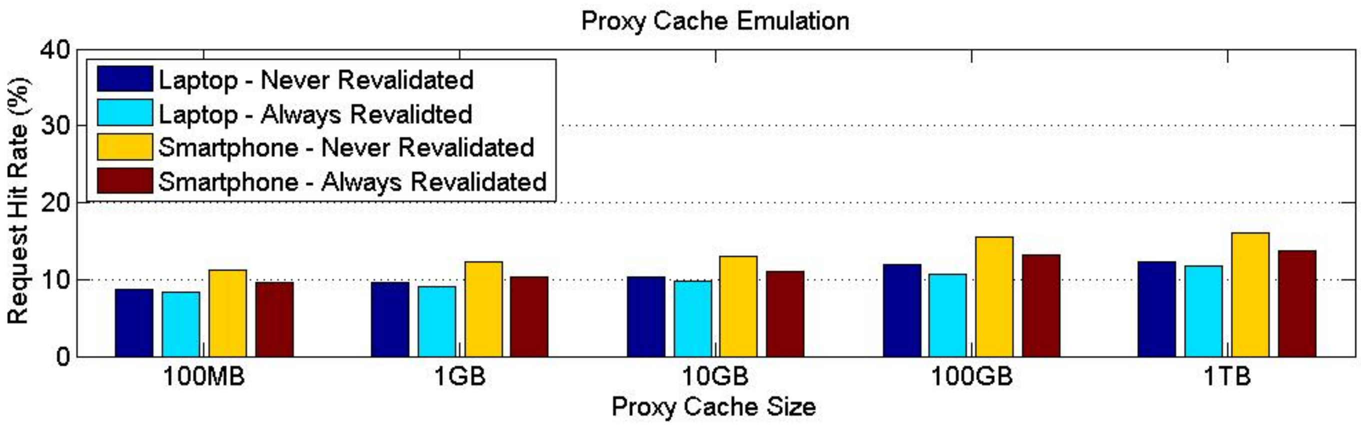
- **Web proxy caches** are used to improve the performance of the Web.
  – Reduce network bandwidth
  – Reduce web server load
  – Improve response time
- **Request Hit Rate:** The percentage of all requests that can be satisfied by searching the cache for a copy of the requested object.
- **Byte Hit Rate:** The percentage of all data that is directly transferred from the cache, rather than the origin server.

Web Traffic: Proxy Cache Size & Freshness

We evaluate the effectiveness based on two configurations for objects that are not fresh in cache:

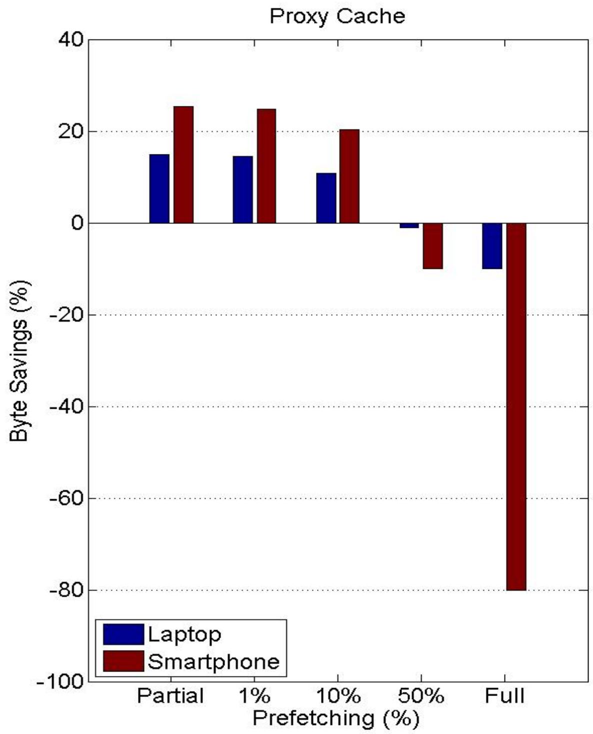
1. *Never Revalidated*: The cached object is the same as the one in the server.
2. *Always Revalidated*: The cached object is different than the one in the server.

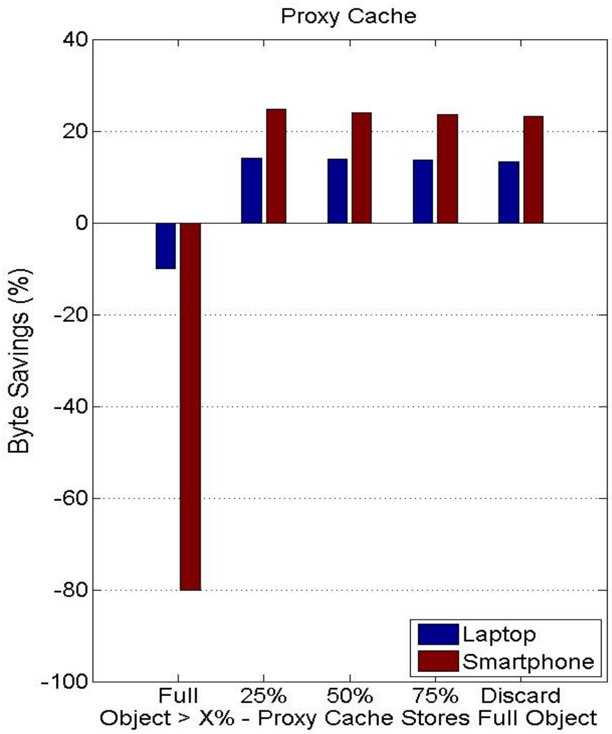




- Diminishing returns ~100GB, hence replacement policies are not relevant any more.
- Savings range from 10-25%, and Request hit rates 10-15%.

Web Traffic: Proxy Cache Storing Policies

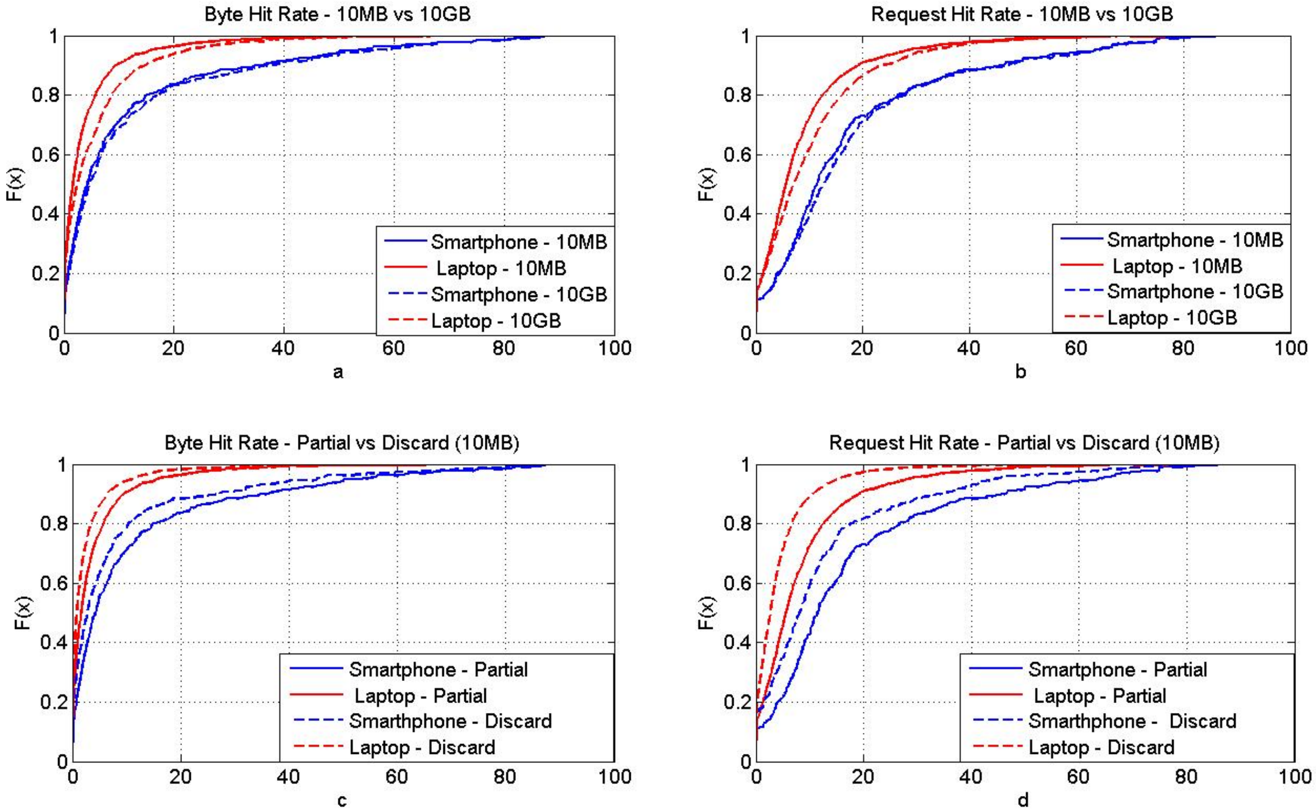




- We evaluate the case where the cache is configured to download X% more data that the data requested by the client.
- **Full download** (cache pre-fetches the whole object) policy results in abusive BW demands in smartphones.
- **Partial storing** (cache stores only what user requested) is the optimum policy.
- A partially downloaded object is cached in its entirety if more than X% of its size has been downloaded by the client.
- 0% corresponds to the **Full download** policy.
- **Discarding** (any partially downloaded object is not cached) is more beneficial than other conditional download policies.

Web Traffic: Browser Cache Efficiency

We replay the IBM trace for each device through an additional simulated cache dedicated solely to that device:



- Current laptop browser caches are more efficient than the smartphone ones.
- A small browser cache (10MB) is sufficient to capture most of the savings in smartphones.
- A browser cache should be able to handle partially downloaded objects.

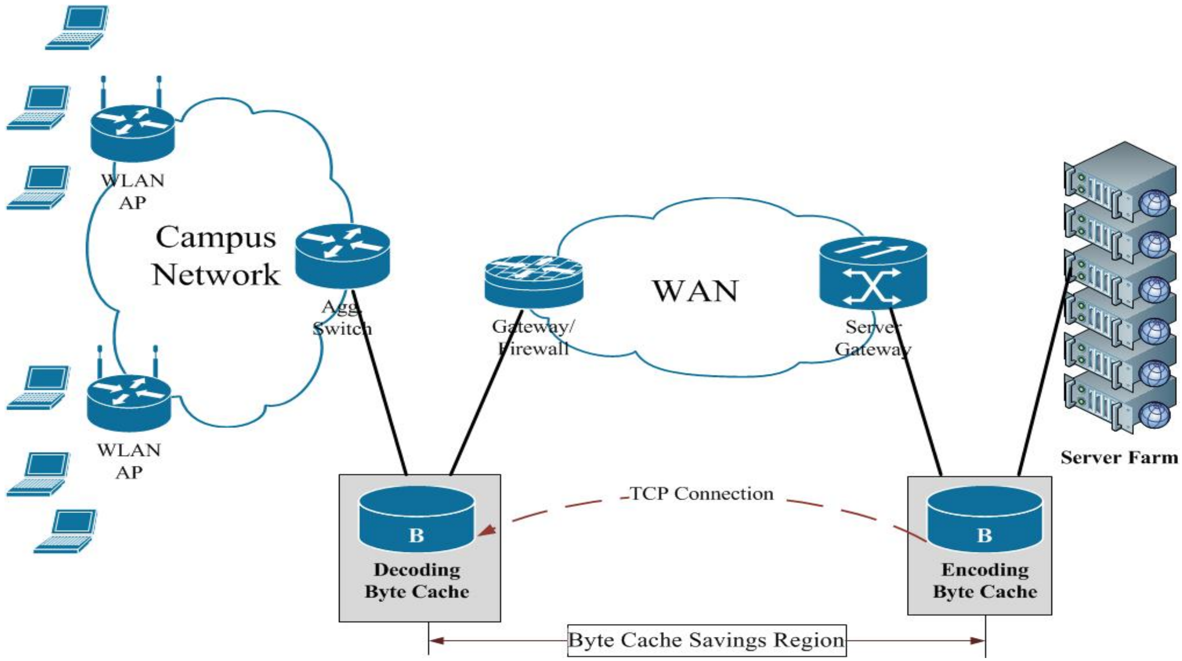
Section 2

Byte Redundancy Elimination in Wireless Networks

Proxy Caches:

- Limited savings: Partially modified objects are treated as different ones.
- Almost 60% of the Web data are uncacheable (based on RFC2616).
- From the cacheable objects, almost 70% may be referenced only once.
- Object revalidation may result in fetching the object from the server.

Byte Cache: Introduction



A Byte Cache is a system of devices that can identify redundancy at the byte level.

- Requires two middleware boxes (encoder & decoder).
- Uses Rabin fingerprinting to generate the hashes.
- Hashes are then used as indices to the content, or to break the content in chunks.

Fingerprint size = 4

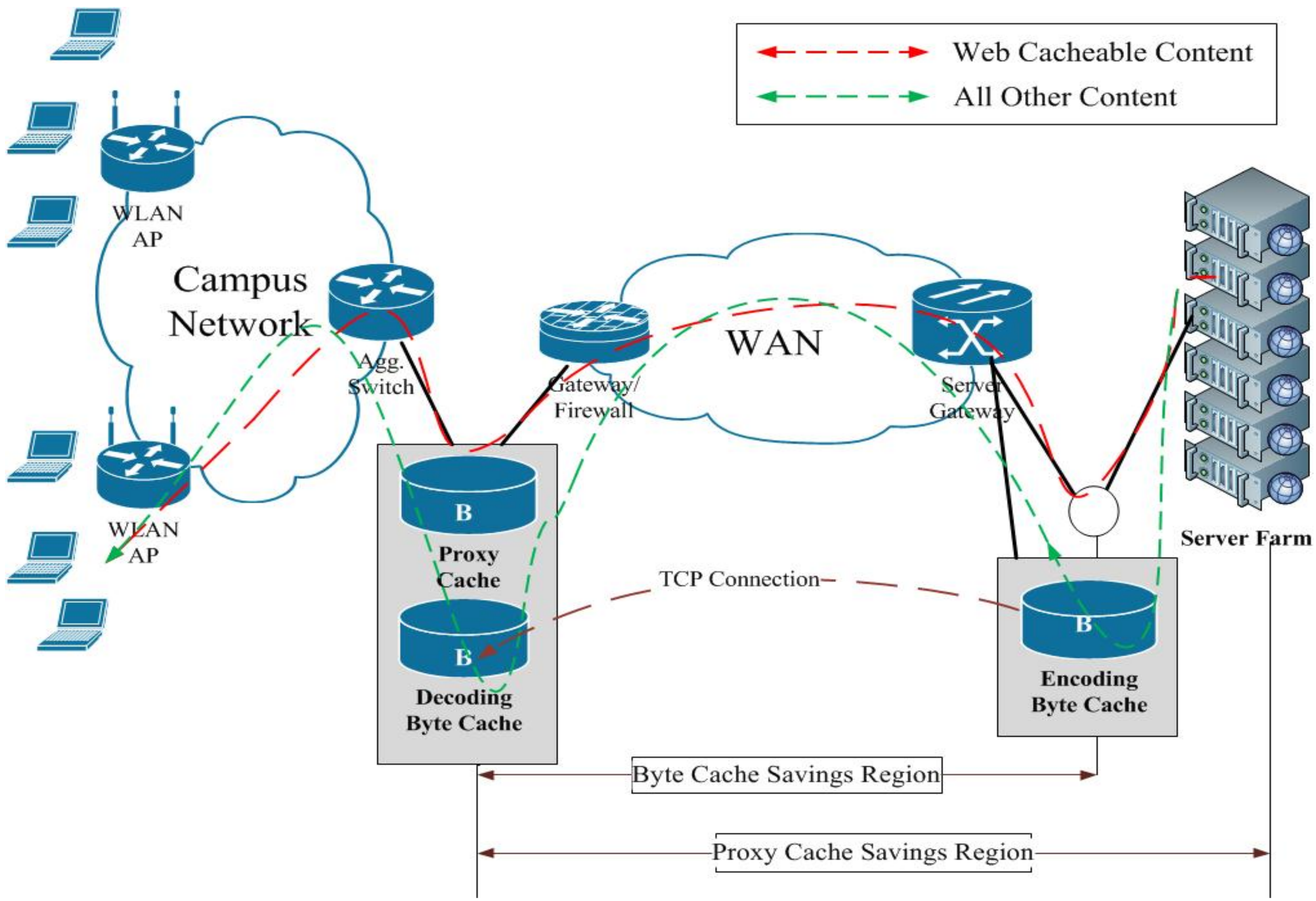
HDD	RAM
<u>Content</u>	<u>Hash</u>
ABCDFEFGHIJ	H(ABCD) H(BCDE) H(CDEF) H(DEFG) H(EFGH) H(FGHI) H(GHIJ)

Packet 1
srcIP: 15.2.1.1
dstIP: 150.150.1.1
Payload: ABCDEFGHIJ

Byte Caches: Issues

- Fingerprint generation is CPU intensive.
  - Can be a bottleneck in high-bandwidth WAN links.
- Requires a lot of memory space.
  - A hash index is required per object in proxy caches vs. per 32B chunks in DRE systems
- Fingerprint generation and chunk storage may be useless for some protocols.
  - E.g. Encrypted traffic.

Hybrid Byte Cache: Static Scheduler

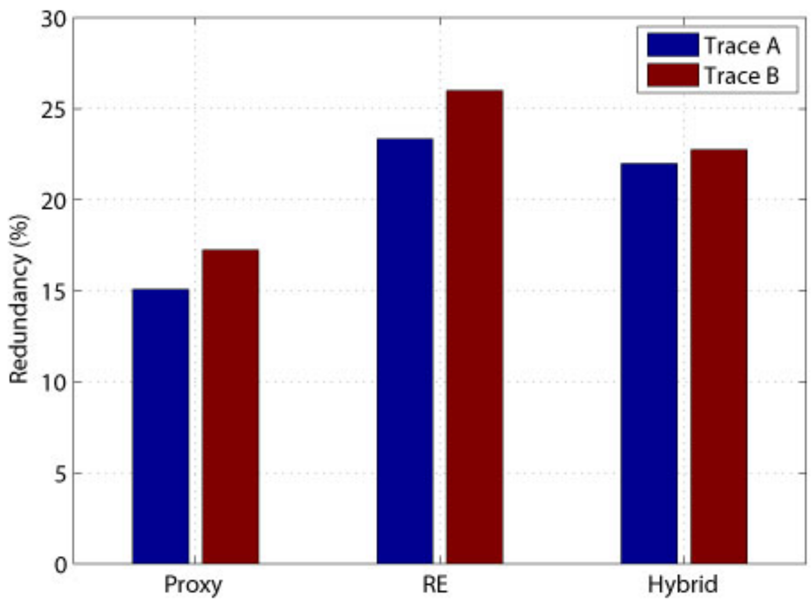


- Scheduler:
  - Web cacheable content is forwarded to a **Proxy Cache** Module
  - Web uncacheable content is forwarded to an **Encoding Byte Cache** Module
  - Other data are sent unprocessed

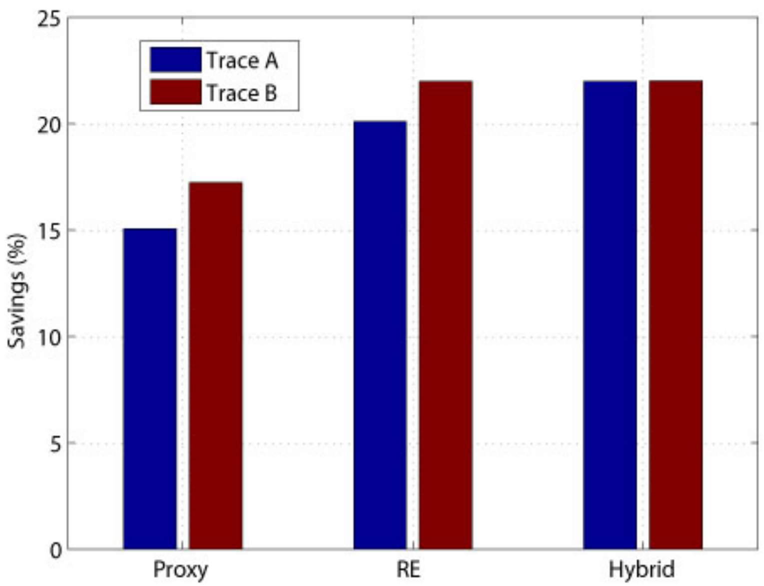
Hybrid Byte Cache: Redundancy & Savings

- Full packet traces captured in IBM (Trace A: 19GB, Trace B: 64GB)
  - Both traces consist of 80% TCP and 75% of Web traffic.

Redundancy



Savings

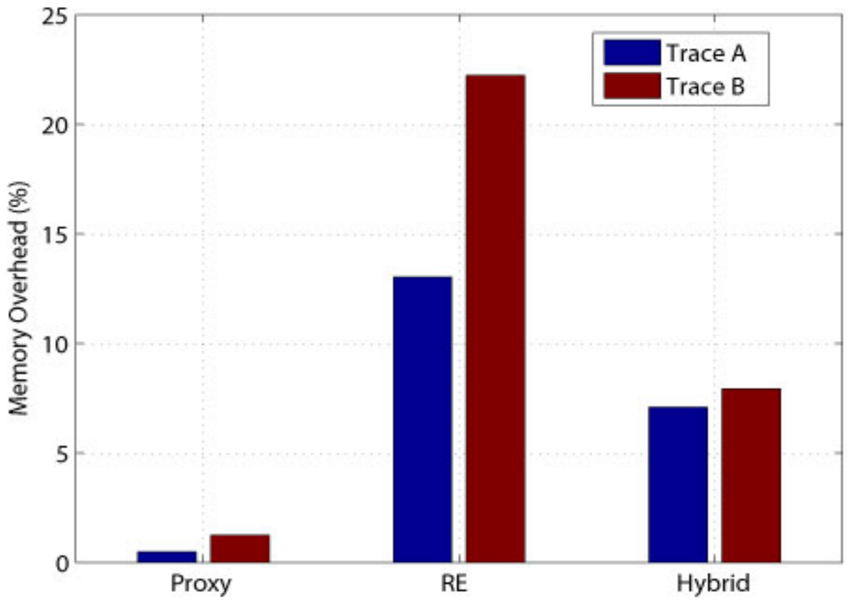


- Redundancy in DRE is better than in Proxy or Hybrid DRE
  - Note that redundancy includes the hash overhead.
  - Providers are mostly interested for Savings.

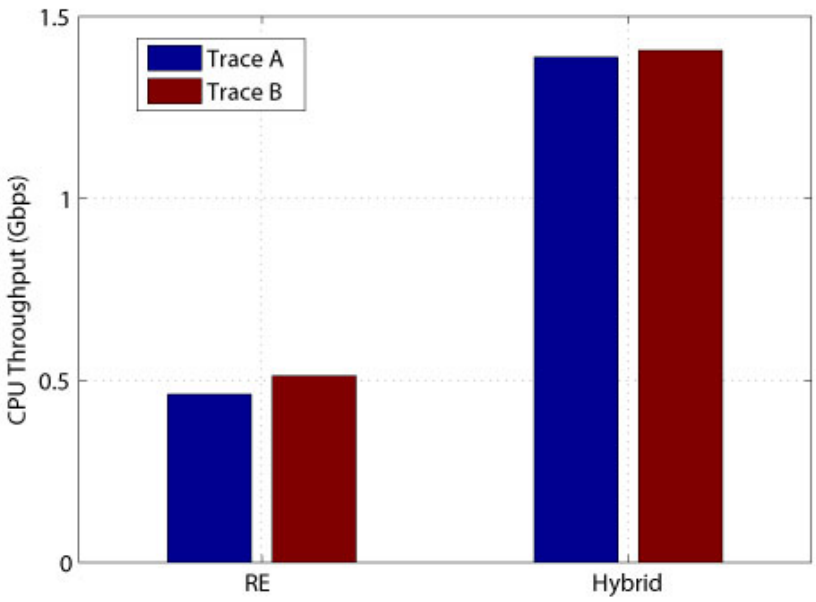
- Hybrid DRE provides more savings than Proxy or DRE.

Hybrid Byte Cache: System Performance

Memory requirement



CPU Throughput



- "Memory Overhead" indicates the amount of RAM needed to store the hashes that correspond to the content.
- Hybrid DRE requires more than half the memory compared to DRE.
- Hybrid DRE increases throughput almost 3 times compared to DRE.
  - Therefore, Hybrid DRE can be installed in faster links.

Conclusion

Summary

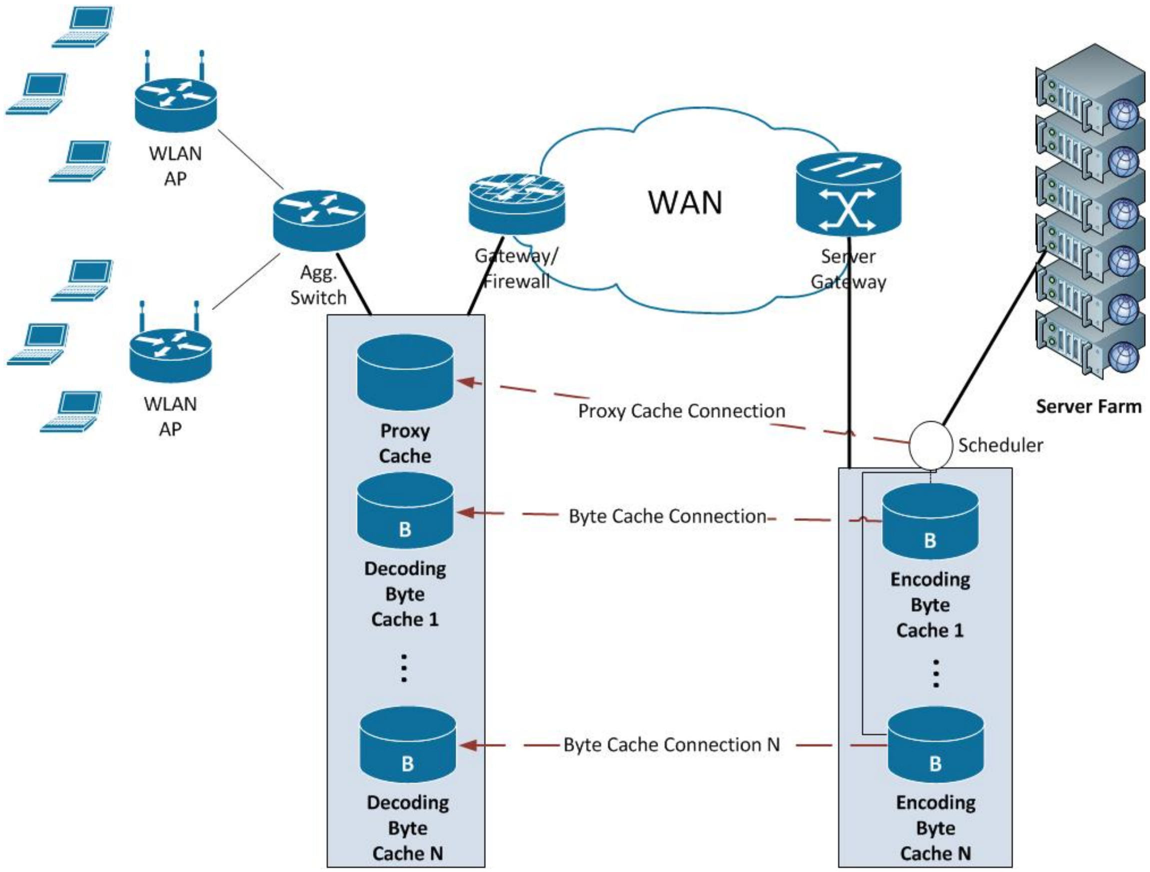
- Differentiated DHCP Lease policy should be implemented in wireless networks.
- A Smartphone vendor should consider adding an extra **10MB** of Browser Cache:
  - ~5% of savings.
- A **100GB,** properly configured proxy cache can provide:
  - 25% of savings for smartphones.
  - 15% of savings in a wireless network.
- A Byte Cache system may provide more savings than a proxy.
- The proposed Hybrid DRE leverages the advantages of both the Proxy Cache and the Byte Cache:
  - Better savings
  - Less CPU cycles
  - Less memory

Future Work at Purdue University

Research Plan

- Collaborations
  - IBM Research, Cisco Systems and Time Warner
  - North Carolina State University and University of Michigan
    - NSF proposals
- Research Areas
  - Data analytics in mobile networks
  - Byte level deduplication
  - Performance analysis & simulations
  - Elasticity in Cloud Computing
  - Applications to the Smart Grid
- Extend Intellectual Property

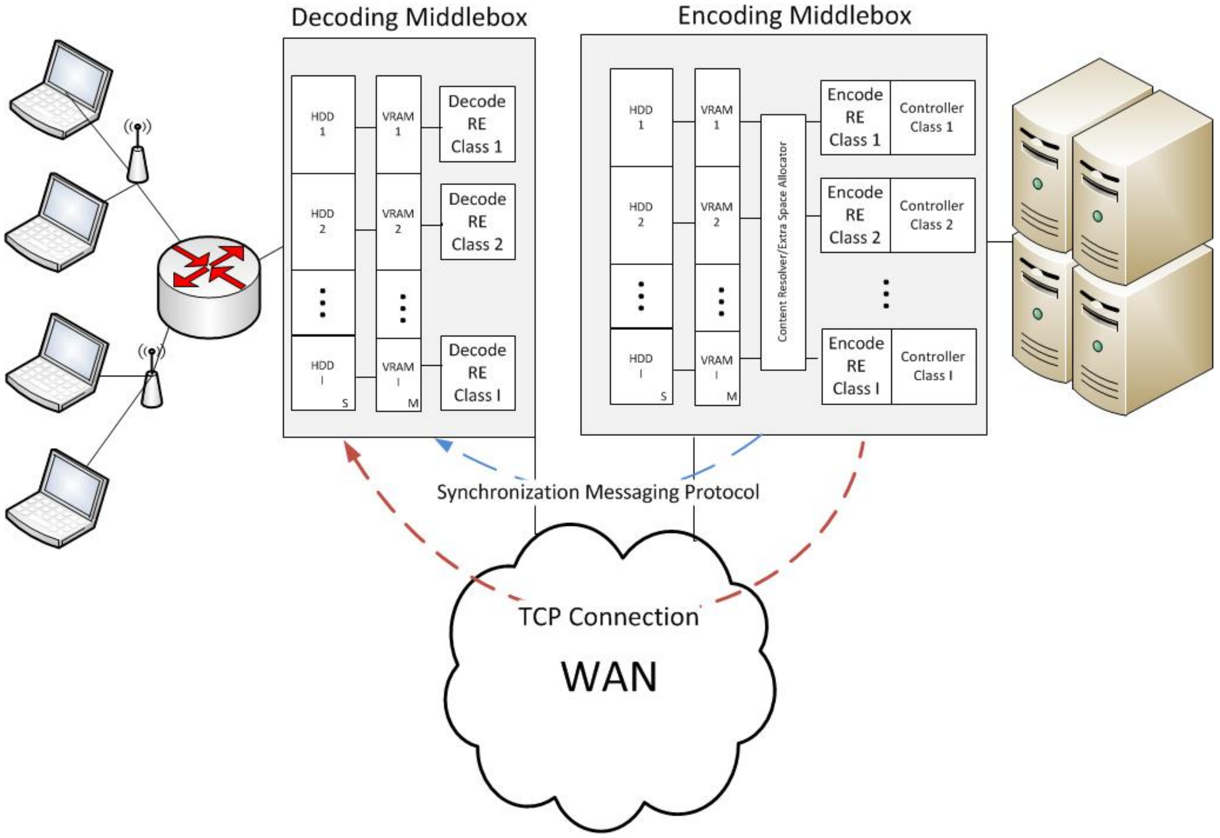
Future Work #1: Dynamic Hybrid DRE



Dynamic Scheduler:

- Based on machine learning, predicts the best caching module for each traffic flow.
- Optimized to take into account the savings and system performance.
- Decreases CPU usage, benefits from parallel processing, increases savings and system failover.

Future Work #2: Quality of Service in Data Deduplication



- Users are differentiated in class categories:
  - Each class processes the flows with a different set of parameters.
- We introduce a controlling mechanism that dynamically allocates memory and space:
  - Per-class controllers monitor the performance and send messages to the central controller such that the SLAs are met.

Thank you!

TEACHING

Teaching Experience

- Teaching:
  - Lab Instructor: Microelectronics
  - TA: Matlab for engineering mathematics

    In class setting with live streaming in a studio

    Interesting observation on how students reach remotely
  - Mentored TA: Advanced Graduate Networking

    Introduced a networking lab through virtualization
- Research in Teaching
  - Funded research on 3D virtual collaboration
- Advising
  - Groups of 4 senior design students
  - MSc Independent student
  - MSc Thesis (won Best Paper Award)

Teaching Philosophy

- *Interesting Teaching quote:*
  - *"Ideal teachers are those who use themselves as bridges over which they invite their students to cross, then having facilitated their crossing, joyfully collapse, encouraging them to create bridges of their own"* --Nikos Kazantzakis

- Teaching Objectives:
  - Focusing on Participants: How am I going to help my participants help this information?
  - Flexible and dynamic content
  - Multidirectional communication
  - Activity driven
  - Being a facilitator (not a presenter)
  - Emphasis on higher order thinking skills (application, synthesis, evaluation)

Courses

- Existing courses that I can contribute
  - CNIT 24000: Data Communications and Networking
  - CNIT 33000: Local Area Networking and Systems Admin
  - CNIT 34500: Internetwork Design and Implementation
  - CNIT 34600: Wireless Networks
  - CNIT 43500: Advanced Network Services
  - CNIT 44500: Advanced Wireless Networks

- Interested in teaching
  - Computer Networks
  - Cloud Computing
  - Data mining in Networking data
  - Computer Simulations and Performance Analysis

Computer Networking

- Book
  - Computer Networking: A top down approach, James F. Kurose, Keith W. Ross.
- Semester Project
  - Socket programming in network services
- Lab
  - Virtualization of Networking Lab: can work with other CoT campuses
- Extensions to certifications
  - Questionnaire from Cisco CCNA/CCIE certifications
  - Work with Cisco Academy
- New ideas in Computer Networks
  - Extend on a paper or thesis
  - Patent/Intellectual Property

Computer Simulation and Performance Modeling

- Book
  - *Simulation with Arena*. 5th Edition, W. David Kelton, Randall P. Sadowski, and David T. Sturrock, by W. McGraw Hill. 2007
  - Computer Simulation Techniques -The Definitive Introduction, Harry Perros.
- Semester Project
  - Develop a discrete event simulator
- Potential Topics:
  - Simulation-based methods for modeling, analyzing, and improving network flows,
  - Discrete-event, process-interaction, continuous, and combined techniques for building complex simulation models,
  - Software tools and statistical techniques for random number and random variate generation,
  - Estimating stochastic simulation inputs, verifying and validating simulation models, and analyzing stochastic simulation outputs,