First Year Review

Information Leakage in Sensor Network Traffic

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Review

- May 2014 – Decmber 2014
  - Background of sensor network
    - Contiki
    - 6lowPAN, CoAP, DTLS
    - tinyDTLS
  - Existing attacks:
    - Content length fingerprinting
      - Generally applicable
      - Application specific
      - Affected by dynamic contents like ads
    - Mutual Information analysis
      - Good coverage over multiple observable variables
      - Computational heavy

Review

- More existing attacks:
  - Compression ratio attack: BREACH, CRIME
    - Efficient
    - Practically harmful
    - Prevented by disabling compression
  - Padding Oracle and Lucky 13
    - Efficient
    - Fixed in latest TLS (Padding Oracle)
    - Requires specific setup (Lucky 13)
    - Latency sensitive (Lucky 13)

Review(cont)

- Reflection
  - Applications are mostly experimental
  - Not much security took into concern

- Plan
  - Start with some simple applications
  - Demonstrate the potential of similar attacks

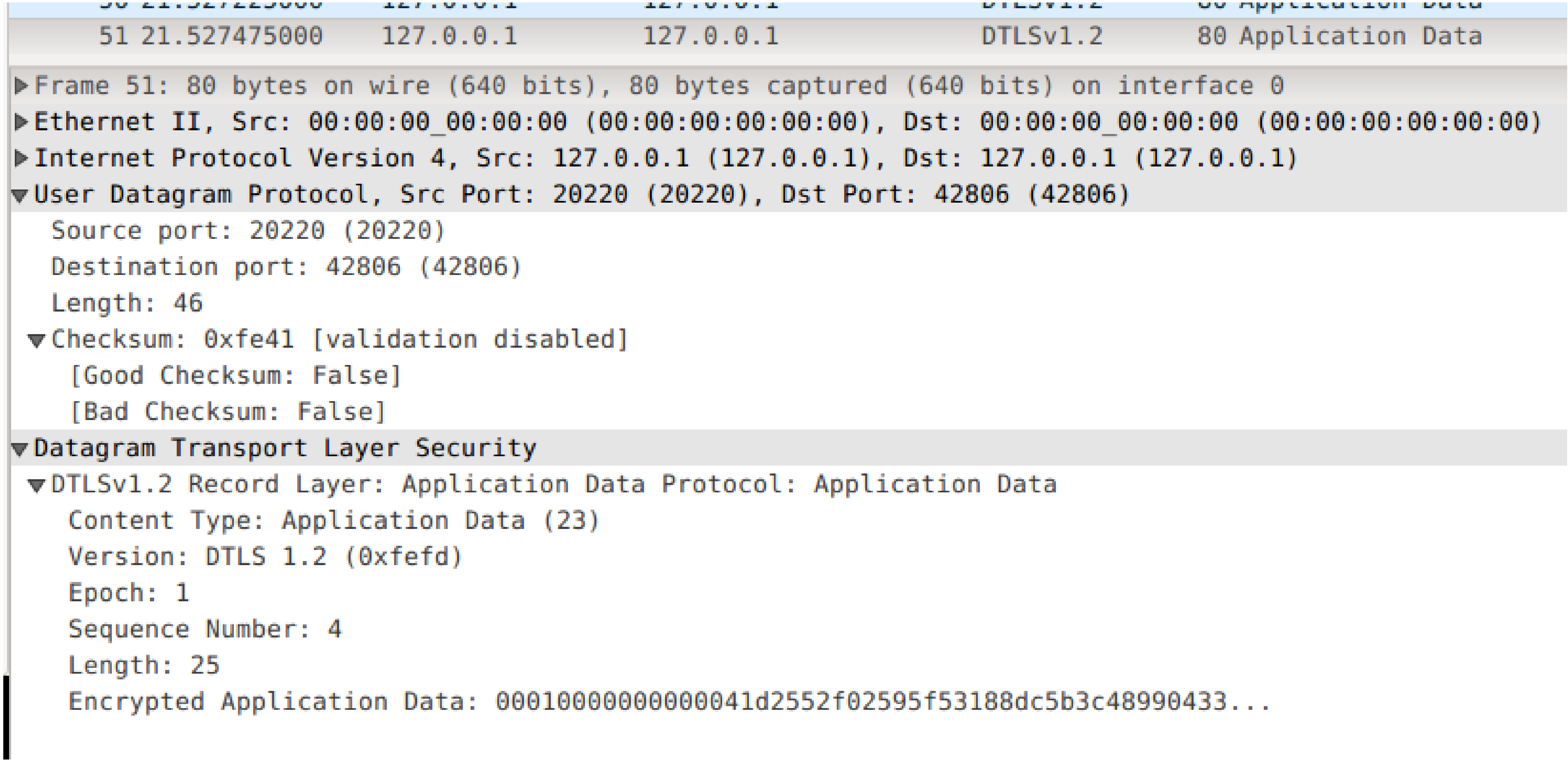
Recent Work

- January 2015 -
  - Developed two toy applications:
    - Odd or Even
    - Leaky Coffee
- Traffic analysis
  - Timestamp*
  - Fields
  - Length

Environment

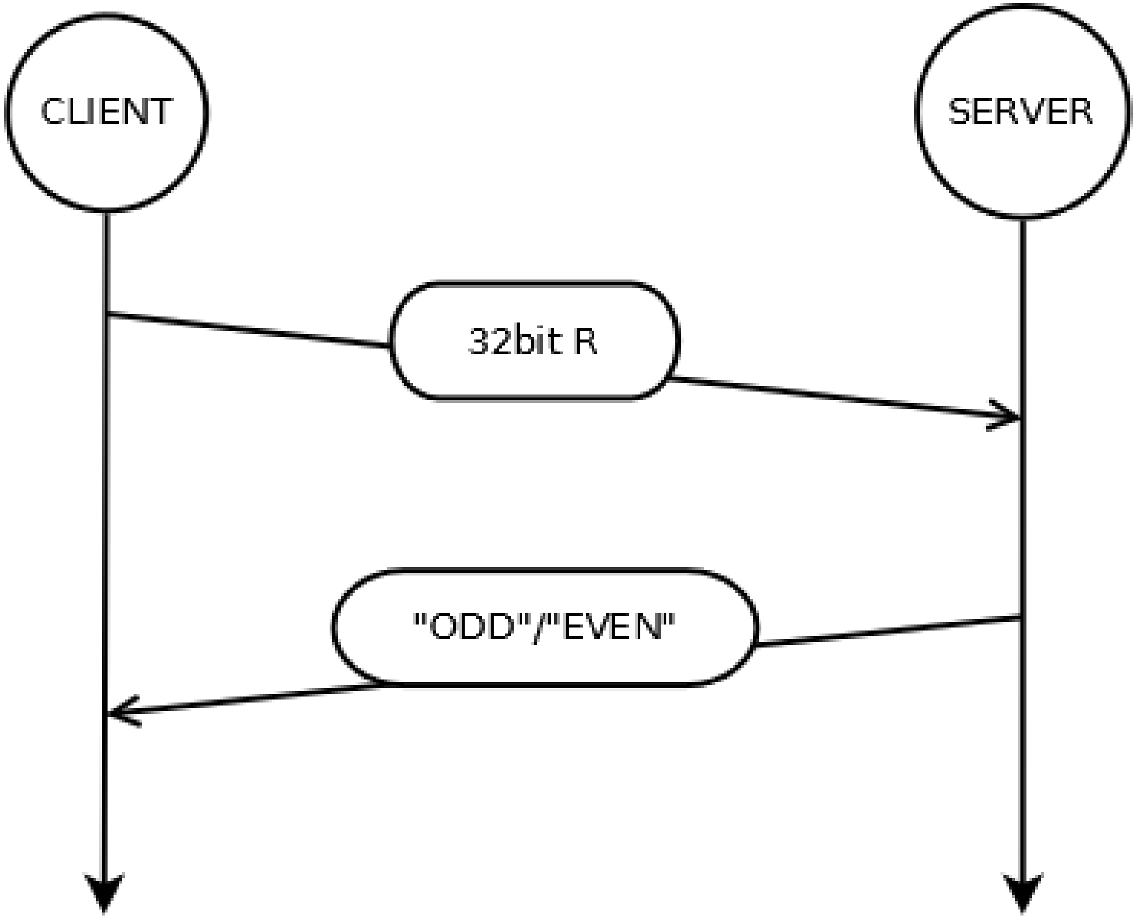
- Ubuntu 14.04
- Locallink
- Tinydtls-0.8.1
  - Pre-shared key
  - TLS_ECDHE_ECDSA_WITH_AES_128_CCM_8
    - There is no padding!
    - Plaintext Length = DTLS length field - 17

Packet



```
       50 21.527225000      127.0.0.1          127.0.0.1                DTLSv1.2        80 Application Data
       51 21.527475000      127.0.0.1          127.0.0.1                DTLSv1.2        80 Application Data
▶Frame 51: 80 bytes on wire (640 bits), 80 bytes captured (640 bits) on interface 0
▶Ethernet II, Src: 00:00:00_00:00:00 (00:00:00:00:00:00), Dst: 00:00:00_00:00:00 (00:00:00:00:00:00)
▶Internet Protocol Version 4, Src: 127.0.0.1 (127.0.0.1), Dst: 127.0.0.1 (127.0.0.1)
▼User Datagram Protocol, Src Port: 20220 (20220), Dst Port: 42806 (42806)
   Source port: 20220 (20220)
   Destination port: 42806 (42806)
   Length: 46
 ▼Checksum: 0xfe41 [validation disabled]
    [Good Checksum: False]
    [Bad Checksum: False]
▼Datagram Transport Layer Security
 ▼DTLSv1.2 Record Layer: Application Data Protocol: Application Data
    Content Type: Application Data (23)
    Version: DTLS 1.2 (0xfefd)
    Epoch: 1
    Sequence Number: 4
    Length: 25
    Encrypted Application Data: 0001000000000041d2552f02595f53188dc5b3c48990433...
```

Odd or Even

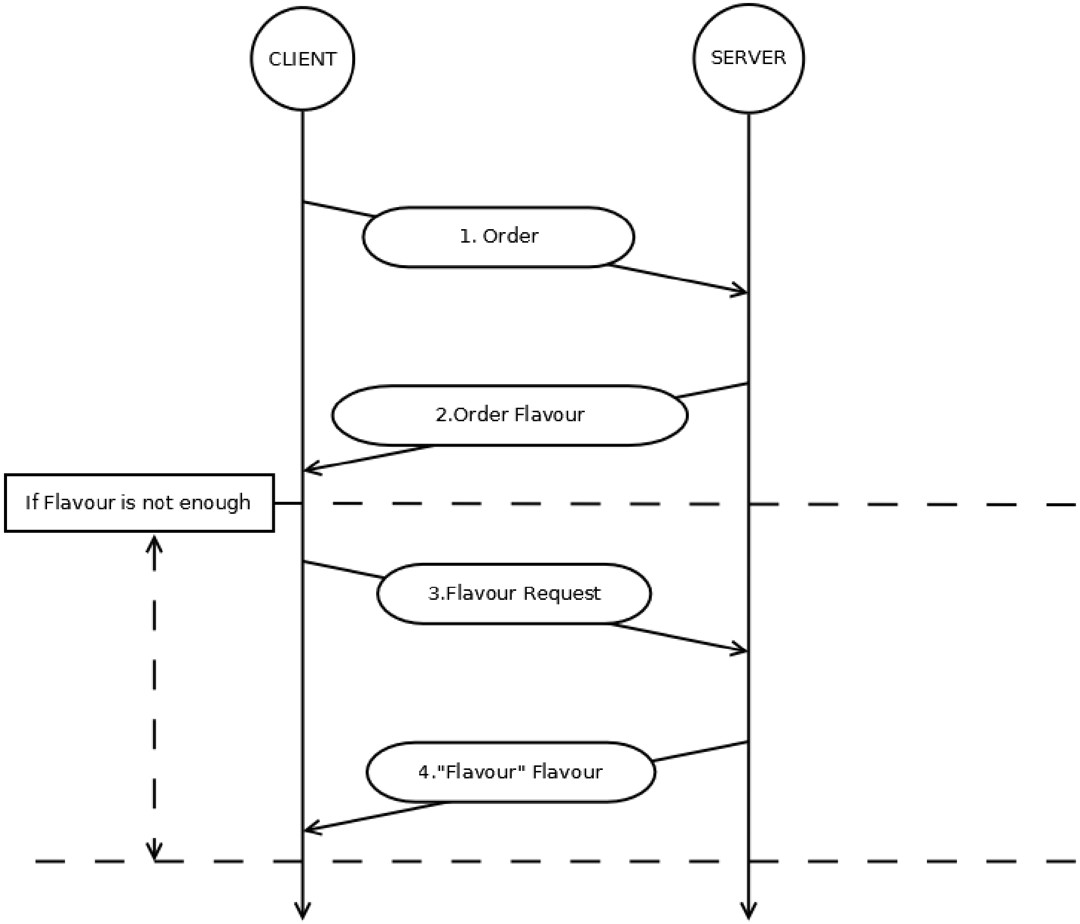


Odd or Even

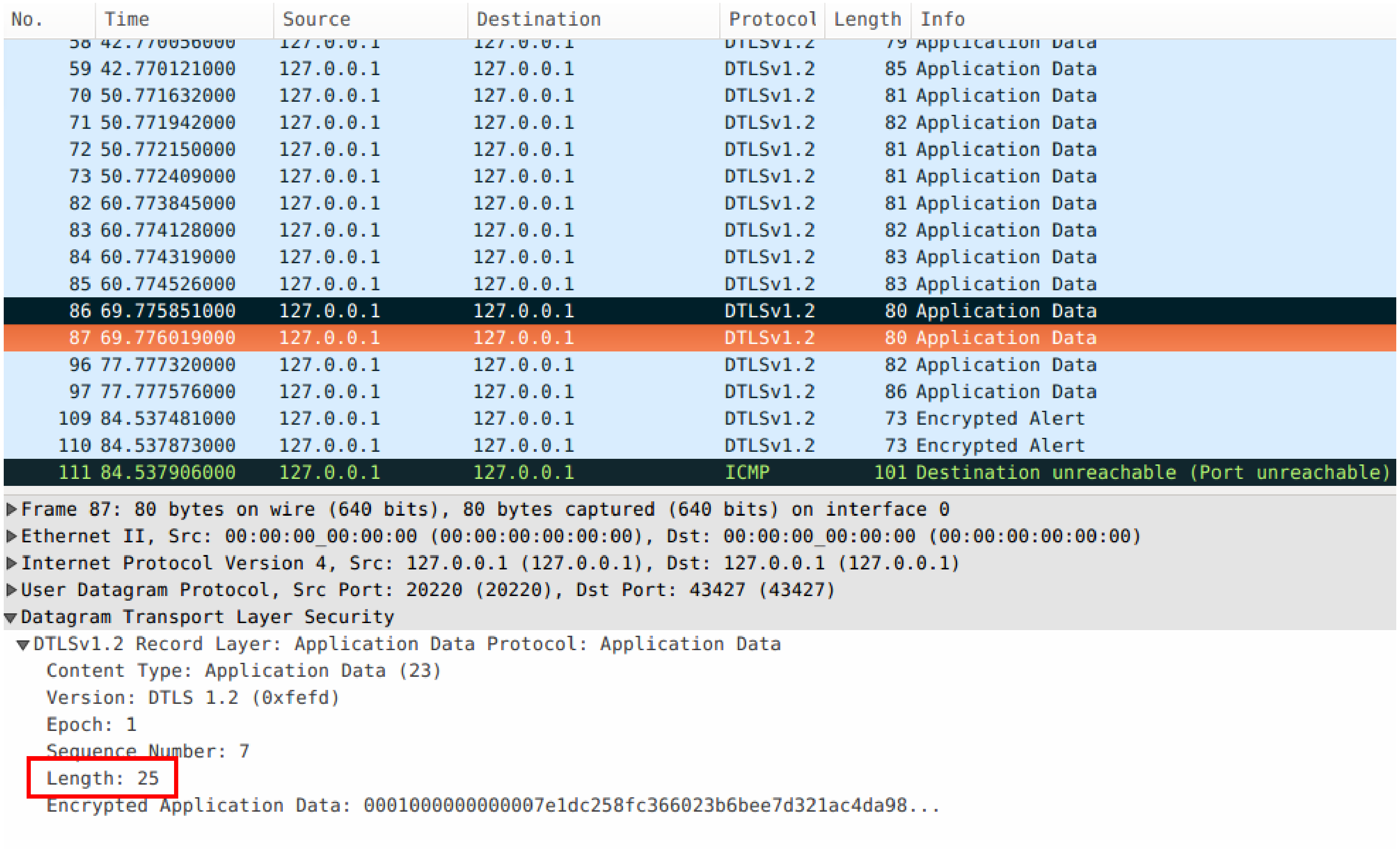
- No padding,
- “EVEN” is 1 byte longer than “ODD”
- Plaintext revealed by length!

- But all other fields seemingly leaks nothing...

Leaky Coffee



Leaky Coffee



```
No.    Time           Source      Destination  Protocol  Length  Info
    58 42.770056000   127.0.0.1   127.0.0.1    DTLSv1.2      79  Application Data
    59 42.770121000   127.0.0.1   127.0.0.1    DTLSv1.2      85  Application Data
    70 50.771632000   127.0.0.1   127.0.0.1    DTLSv1.2      81  Application Data
    71 50.771942000   127.0.0.1   127.0.0.1    DTLSv1.2      82  Application Data
    72 50.772150000   127.0.0.1   127.0.0.1    DTLSv1.2      81  Application Data
    73 50.772409000   127.0.0.1   127.0.0.1    DTLSv1.2      81  Application Data
    82 60.773845000   127.0.0.1   127.0.0.1    DTLSv1.2      81  Application Data
    83 60.774128000   127.0.0.1   127.0.0.1    DTLSv1.2      82  Application Data
    84 60.774319000   127.0.0.1   127.0.0.1    DTLSv1.2      83  Application Data
    85 60.774526000   127.0.0.1   127.0.0.1    DTLSv1.2      83  Application Data
    86 69.775851000   127.0.0.1   127.0.0.1    DTLSv1.2      80  Application Data
    87 69.776019000   127.0.0.1   127.0.0.1    DTLSv1.2      80  Application Data
    96 77.777320000   127.0.0.1   127.0.0.1    DTLSv1.2      82  Application Data
    97 77.777576000   127.0.0.1   127.0.0.1    DTLSv1.2      86  Application Data
   109 84.537481000   127.0.0.1   127.0.0.1    DTLSv1.2      73  Encrypted Alert
   110 84.537873000   127.0.0.1   127.0.0.1    DTLSv1.2      73  Encrypted Alert
   111 84.537906000   127.0.0.1   127.0.0.1    ICMP         101  Destination unreachable (Port unreachable)

▶Frame 87: 80 bytes on wire (640 bits), 80 bytes captured (640 bits) on interface 0
▶Ethernet II, Src: 00:00:00_00:00:00 (00:00:00:00:00:00), Dst: 00:00:00_00:00:00 (00:00:00:00:00:00)
▶Internet Protocol Version 4, Src: 127.0.0.1 (127.0.0.1), Dst: 127.0.0.1 (127.0.0.1)
▶User Datagram Protocol, Src Port: 20220 (20220), Dst Port: 43427 (43427)
▼Datagram Transport Layer Security
 ▼DTLSv1.2 Record Layer: Application Data Protocol: Application Data
    Content Type: Application Data (23)
    Version: DTLS 1.2 (0xfefd)
    Epoch: 1
    Sequence Number: 7
    Length: 25
    Encrypted Application Data: 0001000000000007e1dc258fc366023b6bee7d321ac4da98...
```

Leaky Coffee

- Existence of a packet:
  - A session taking place
- Timestamp:
  - Segmenting packets by session
- Length:
  - Constructing a channel to “decode” plaintext

Leaky Coffee

W(Length|*Order*)	5 bytes	8 bytes	9 bytes	Prob(*Order*)
“AMERICANO”			1	1/4
“CAPPUCINO”			1	1/4
“MOCHA”	1			1/4
“ESPRESSO”		1		1/4

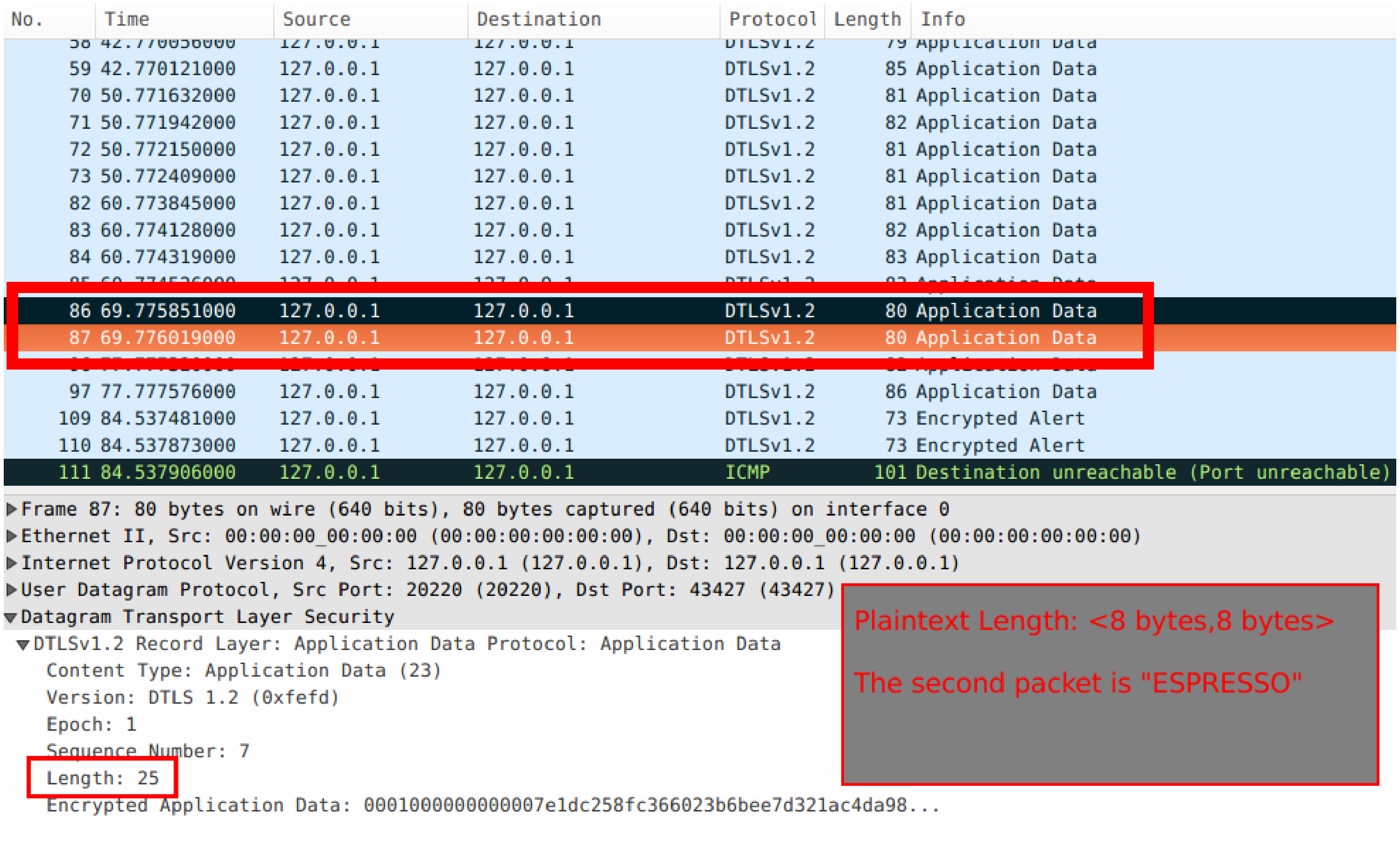
- Plaintext-Length channel for *Order*
  - Prob(*Order*) is known from the implementation
  - Revert it to construct our “decoding” channel!

Leaky Coffee

W(*Order*|Length)	“AMERICANO”	“CAPPUCINO”	“ESPRESSO”	“MOCHA”
5 bytes				1
8 bytes			1	
9 bytes	1/2	1/2		

- This channel decodes length to *Order*
- The attack can be further improved by analysing packets jointly

Leaky Coffee



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    84 60.774319000      127.0.0.1     127.0.0.1       DTLSv1.2      83 Application Data
    85 60.774526000      127.0.0.1     127.0.0.1       DTLSv1.2      83 Application Data
    86 69.775851000      127.0.0.1     127.0.0.1       DTLSv1.2      80 Application Data
    87 69.776019000      127.0.0.1     127.0.0.1       DTLSv1.2      80 Application Data
    88 77.777320000      127.0.0.1     127.0.0.1       DTLSv1.2      82 Application Data
    97 77.777576000      127.0.0.1     127.0.0.1       DTLSv1.2      86 Application Data
   109 84.537481000      127.0.0.1     127.0.0.1       DTLSv1.2      73 Encrypted Alert
   110 84.537873000      127.0.0.1     127.0.0.1       DTLSv1.2      73 Encrypted Alert
   111 84.537906000      127.0.0.1     127.0.0.1       ICMP         101 Destination unreachable (Port unreachable)

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```

Plaintext Length: <8 bytes,8 bytes>

The second packet is "ESPRESSO"

Reflection

- Similar to content length fingerprinting
  - DTLS instead of TLS
  - No noise
- Constrains
  - Application too simple (low entropy plaintext)
  - Some other cipher suites have padding
  - Timestamp may be affected by underlying protocols
  - Requires pre-knowledge of plaintext distribution

Future Plan

- Wrap up the “toys”
  - Different pre-knowledge?
  - Other types of attack?
  - Countermeasure?
- Other DTLS implementation
  - e.g. PolarSSL (https://tls.mbed.org/)
- Apply the attacks on some real world traffic
  - (If we can get in touch with any...)

Other Activities

- Real World Crypto 2015
  - 06/01/2015 ~ 09/01/2015