Enhancing Multimedia QoE via More Effective Time Synchronisation over 802.11 Networks

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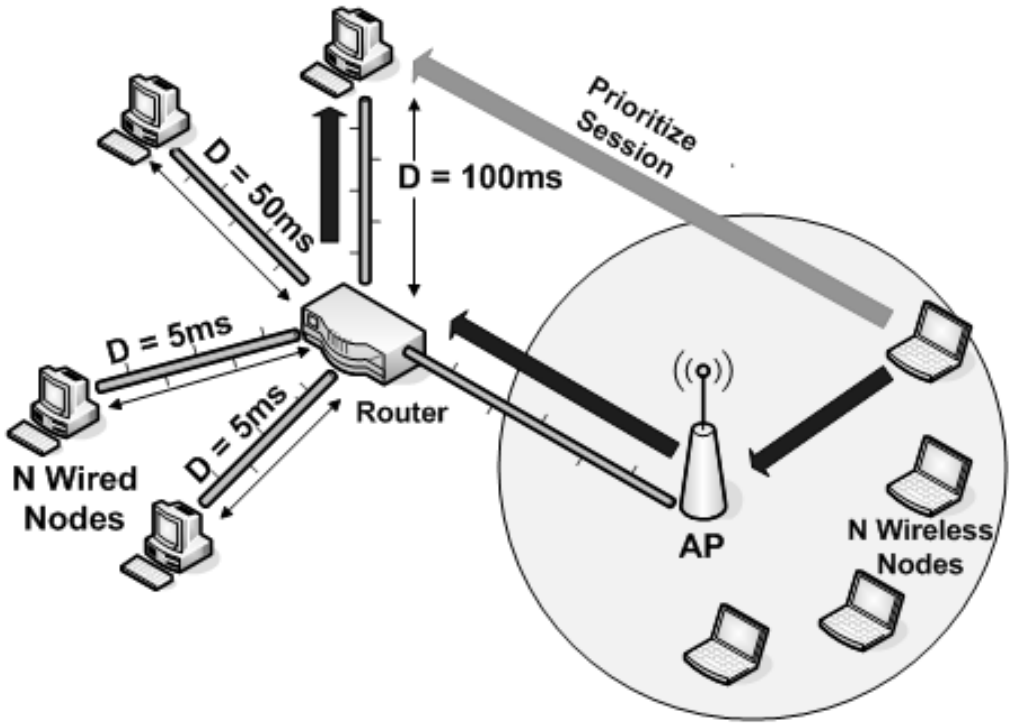
Outline

- **Multimedia & Synchronisation**
- **Computer Clocks, Synchronisation Terminology & Techniques**
- **802.11, NTP & Issues**
- **Simulations**
- **Delay Determination Technique**
- **Experiments & Results**
- **Questions**

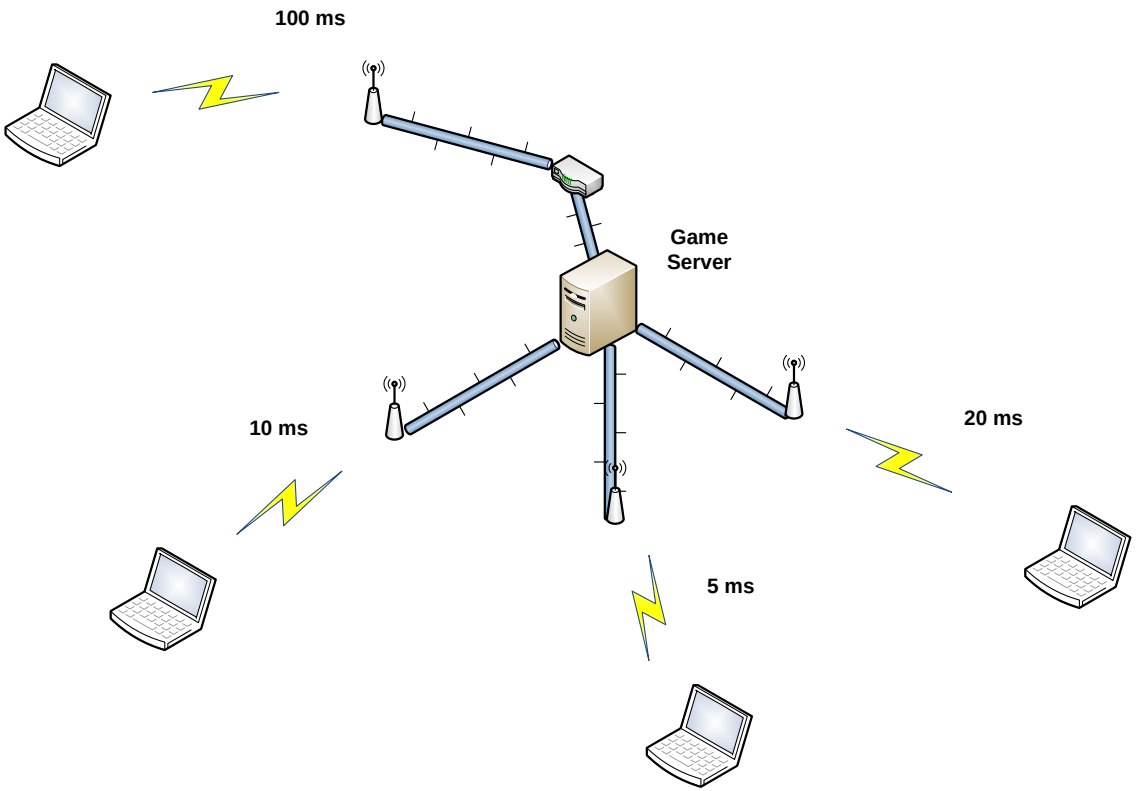
Growing Role of Synchronisation

- **VoIP** (Voice over IP)



Growing Role of Synchronisation

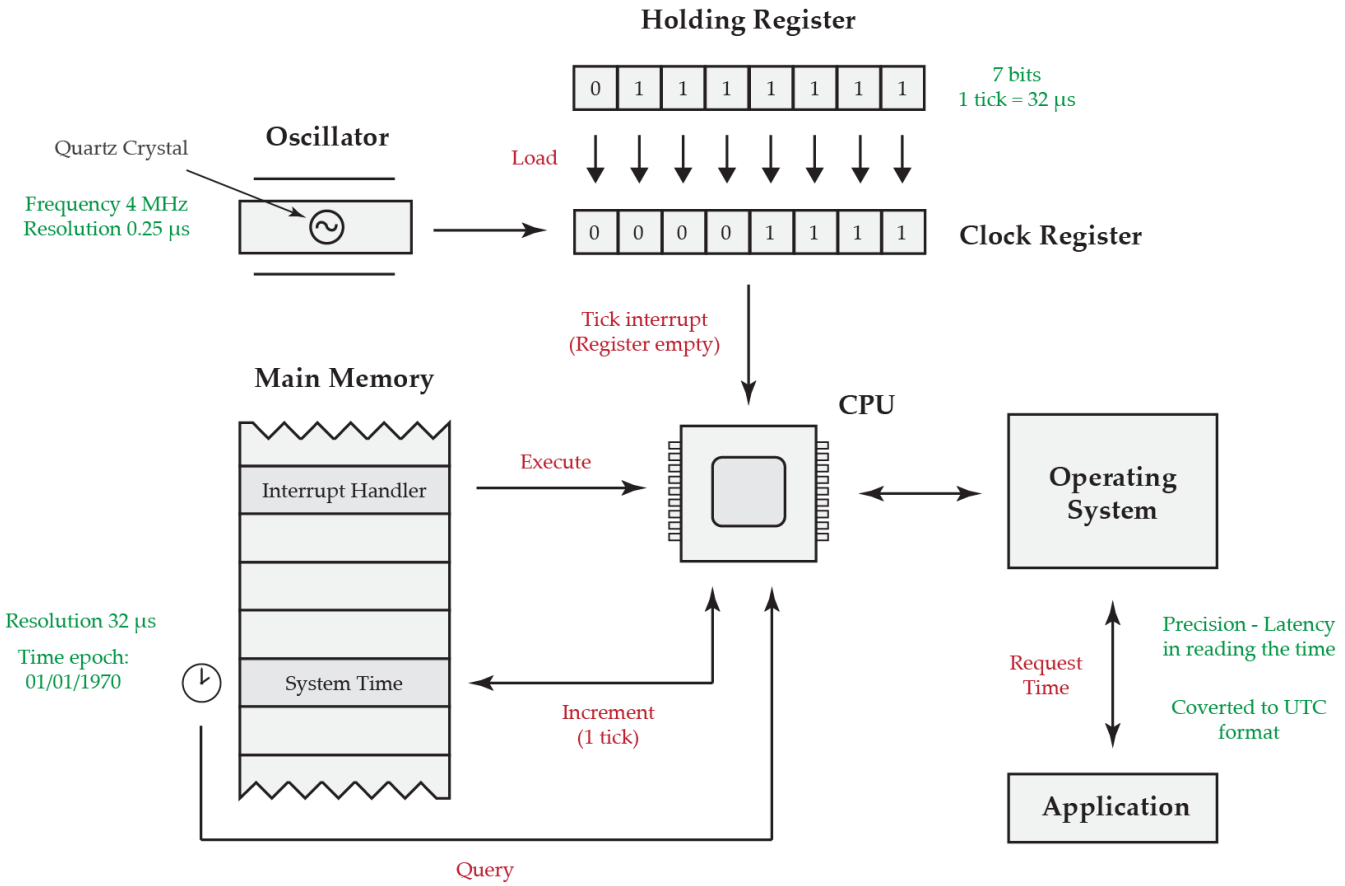
- **MMOG** (Massive Multiplayer Online Game)



WebRTC

- **WebRTC**
  - Open source project released by Google in 2011
  - Aim to equip browsers with RTC capabilities
  - W3C standardising ECMAscript API's
  - IETF standardising underlying RTC protocols (Rtcweb WG)
- **WebRTC & VoIP**
  - Techniques to cope with variable packet latencies (Jitter buffer and play-out strategy algorithms)
  - WebRTC NetEQ component
  - NetEQ can benefit from packet delay information – improve QoS
  - Synchronisation of wireless nodes important

System Clock Operation



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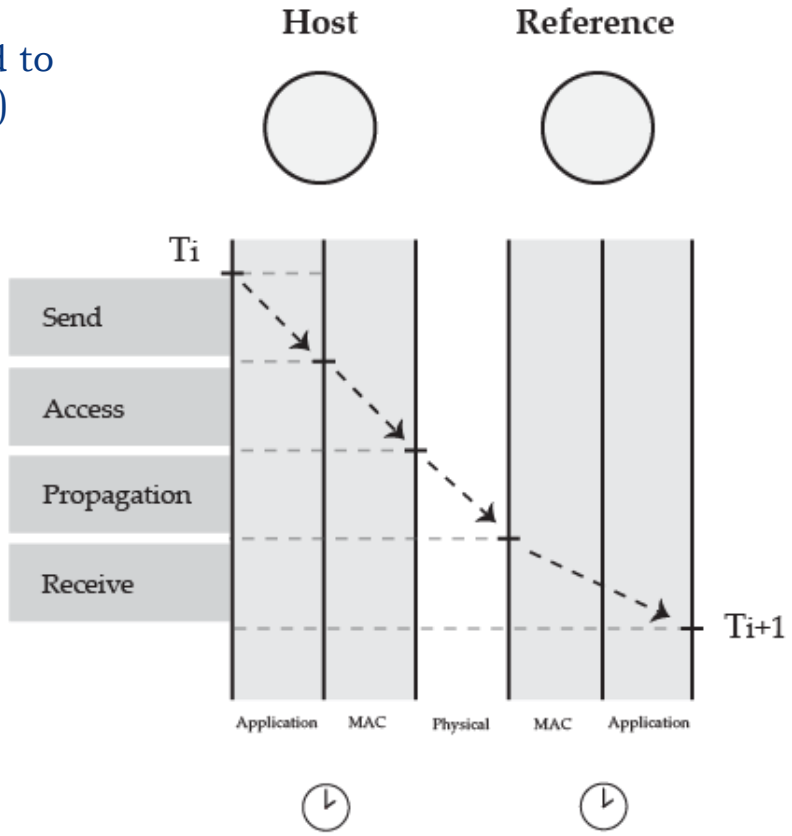
Synchronisation Terminology

- **Host** & **Reference**
- **Offset** Time difference between a host time and a reference time
  - Indication of clock **accuracy**
  - Denoted by θ
- **Skew** Rate of change of host's time with respect to reference's time
  - Influenced by oscillator **precision/accuracy**
  - Denoted by λ
- **Drift** Rate of change of host's skew with respect to reference's time
  - Influenced by oscillator **stability**
  - Denoted by φ

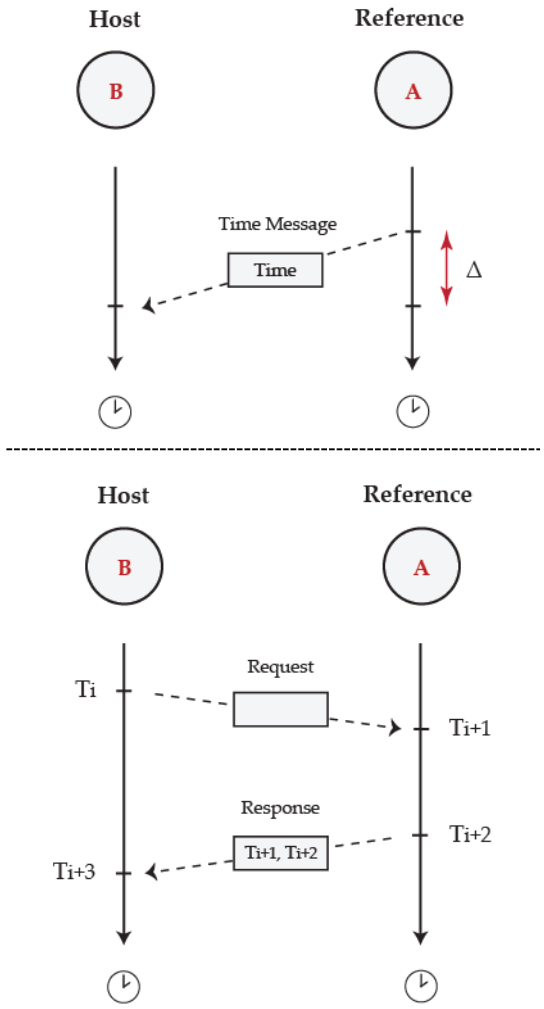
Sources of Synchronisation Error

- **Send Time**
  - Timestamp, **construct** message & send to **NIC** (system load, system call latencies)
- **Access Time**
  - Access communication medium
  - (MAC rules)
- **Propagation Time**
  - **Traverse link** between sender and receiver
- **Receive Time**
  - NIC **receive** & **decode** time and time interval before timestamp



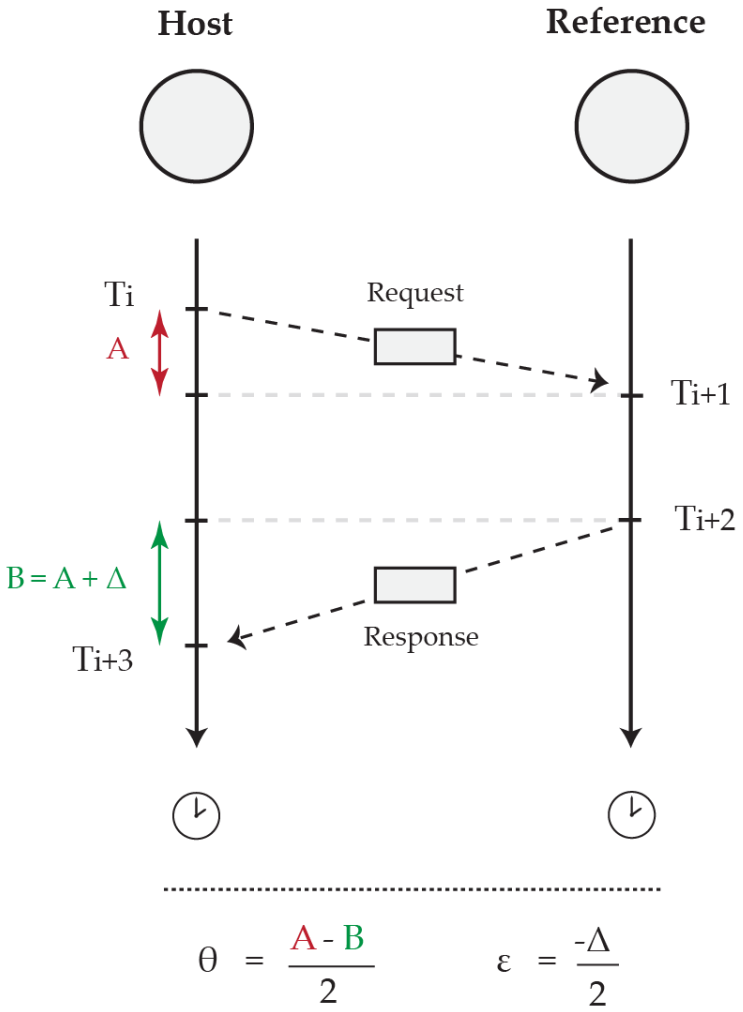
Synchronisation Techniques

- **Uni-directional Synchronisation**
  - **Host** sets its time to the value received in a time message from a **reference**
- **Round-trip Synchronisation**
  - Two-way message exchange
  - Host obtains timestamps T_i, T_{i+1}, T_{i+2} and T_{i+3}
  - Determines **round-trip delay (δ)** and **offset (θ)**
  - $\delta = (T_{i+3} - T_i) - (T_{i+2} - T_{i+1})$
  - $\theta = (T_{i+1} - T_i) + (T_{i+2} - T_{i+3})/2$

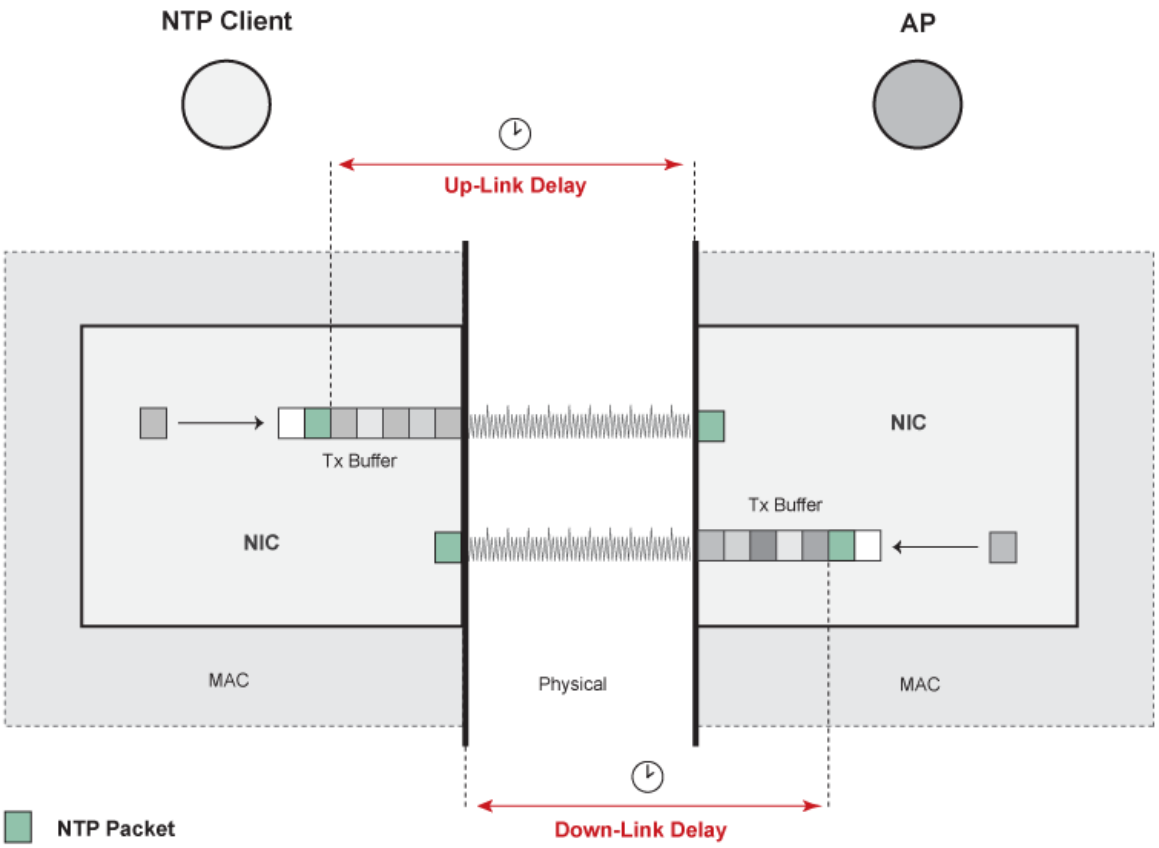


Synchronisation in WiFi Networks

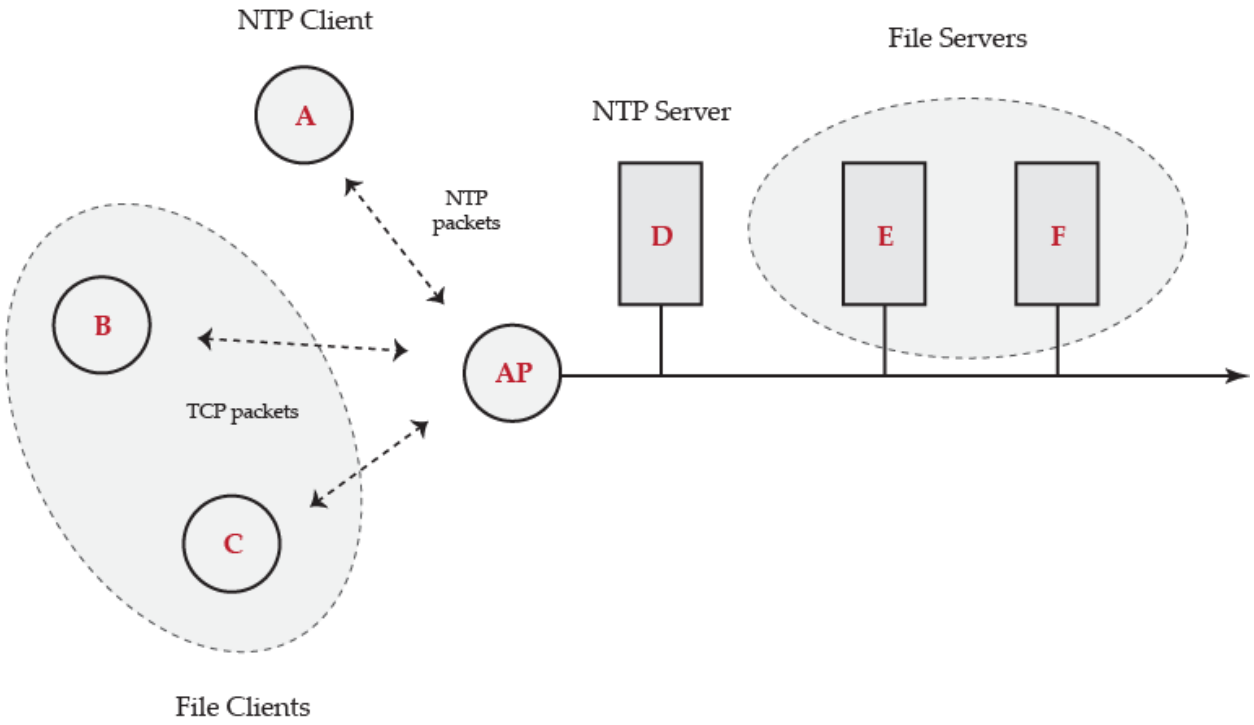
- **Offset**
  - $A = T_{i+1} - T_i$
  - $B = T_{i+3} - T_{i+2}$
  - $\theta = (T_{i+1} - T_i) - (T_{i+3} - T_{i+2})/2$
- **WiFi/802.11**
  - Access & buffer delays
- **NTP**
  - Degrade performance



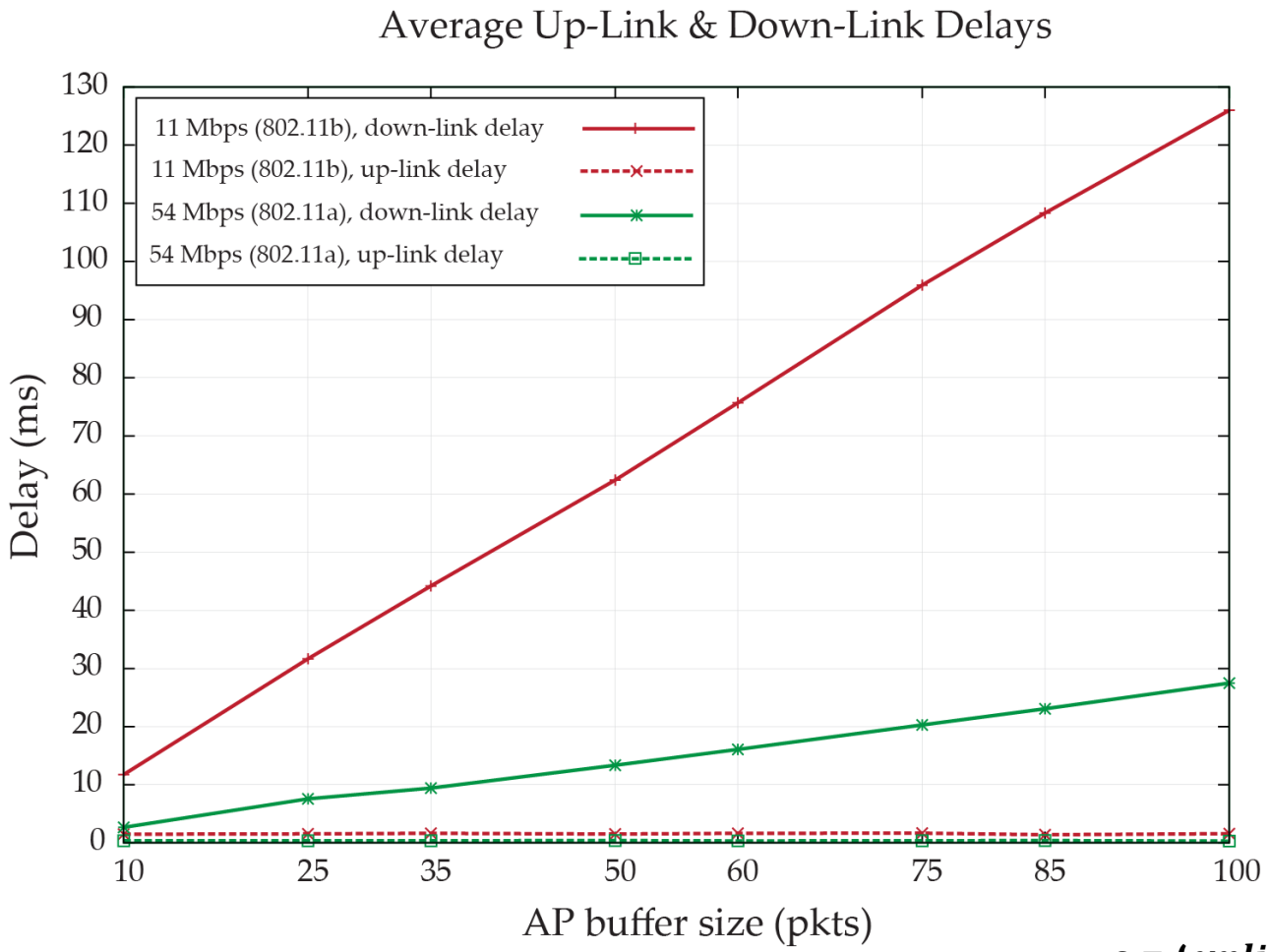
Up-link & Down-link Delays



Simulations – NS3

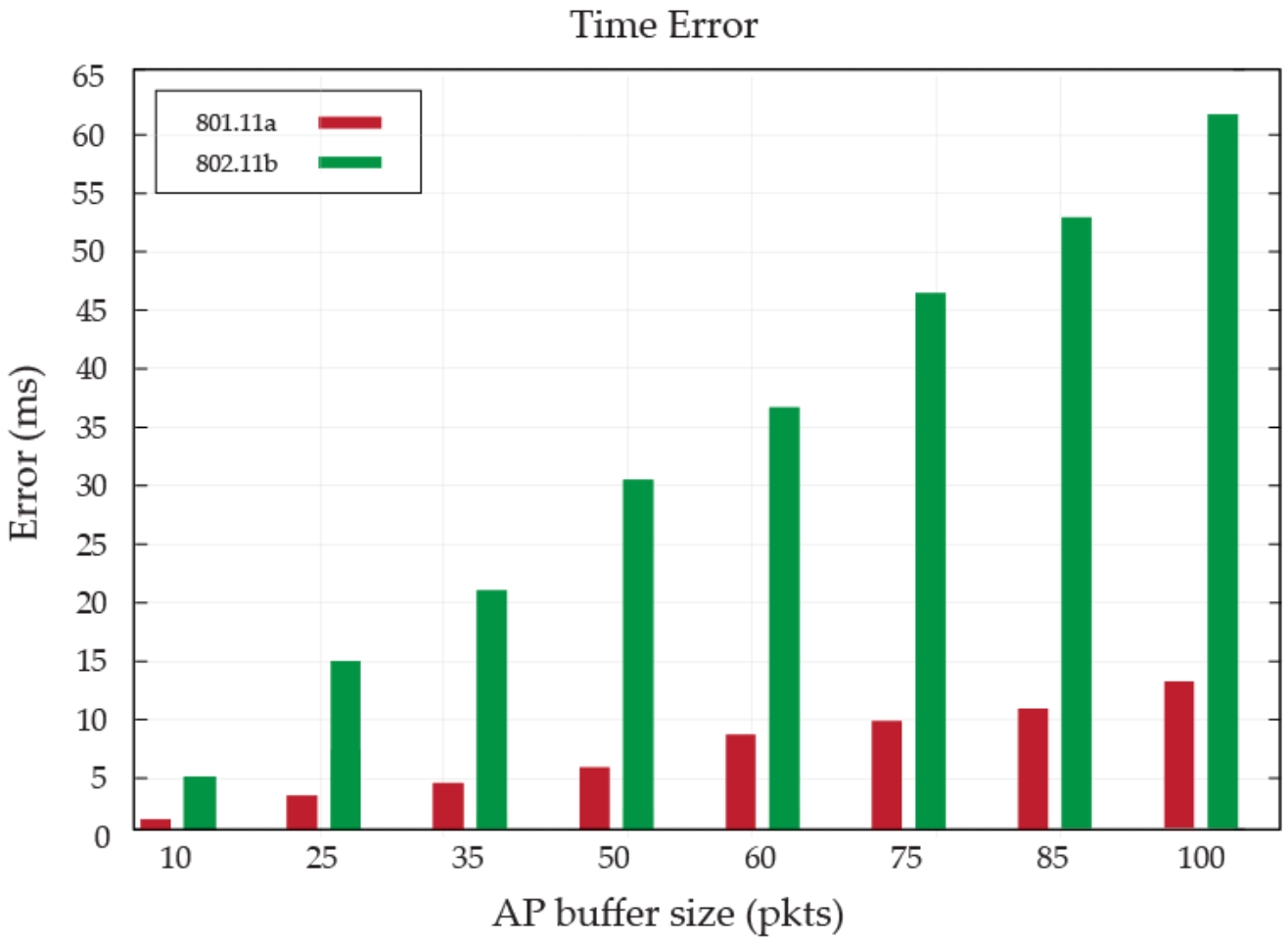


Simulations – NS3

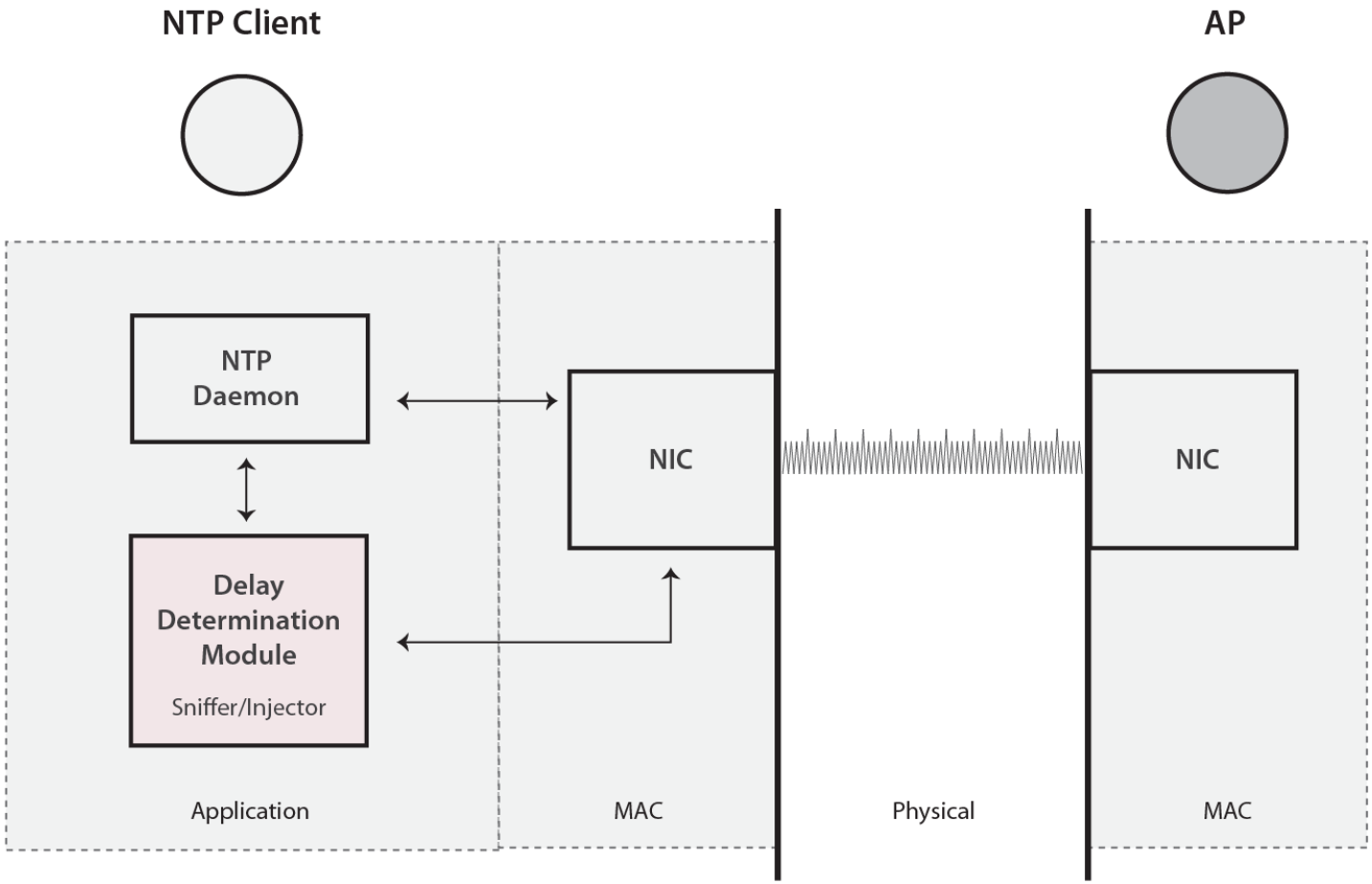


$\epsilon = (uplink) - (downlink)/2$

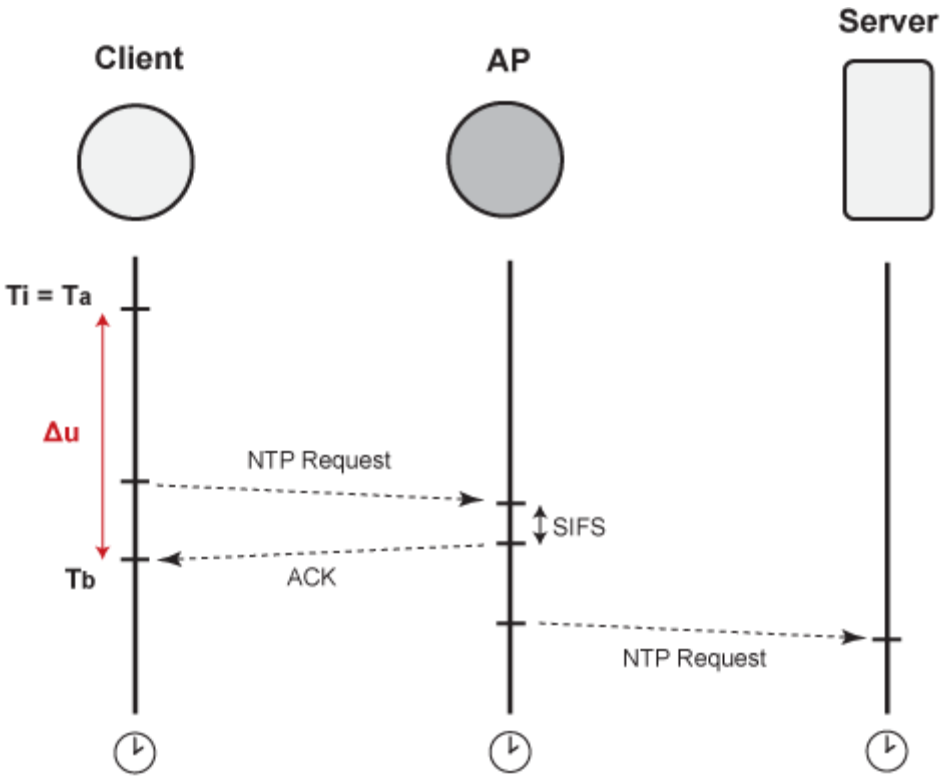
Simulations – NS3



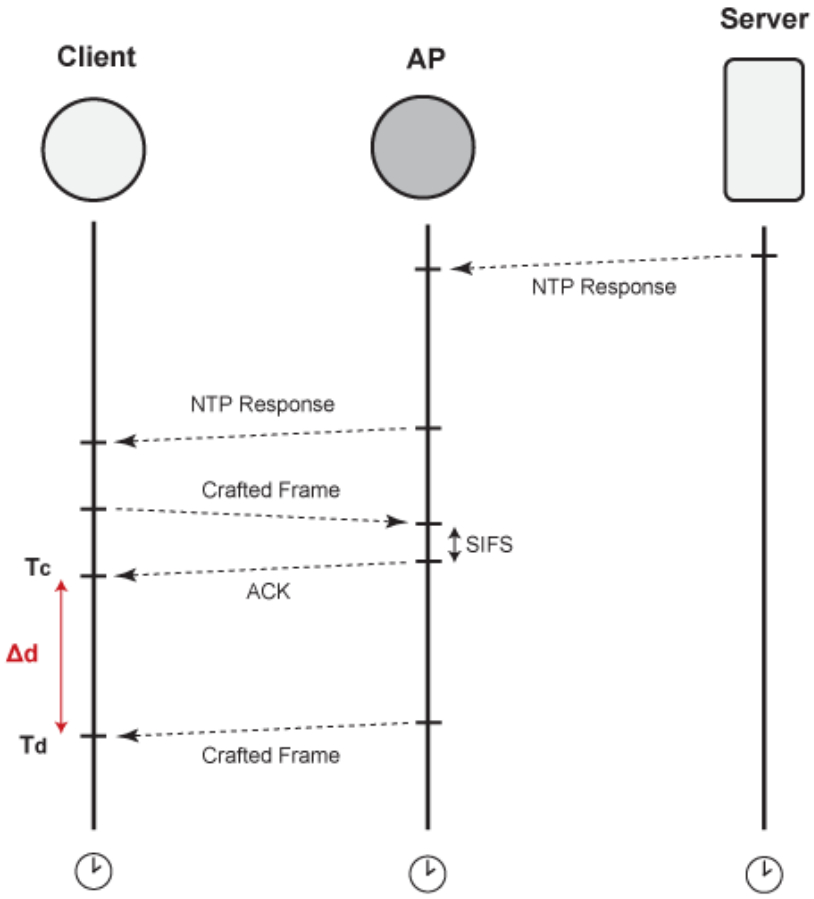
Solution


NTP Client
AP
NTP Daemon
Delay Determination Module
Sniffer/Injector
NIC
NIC
Application
MAC
Physical
MAC

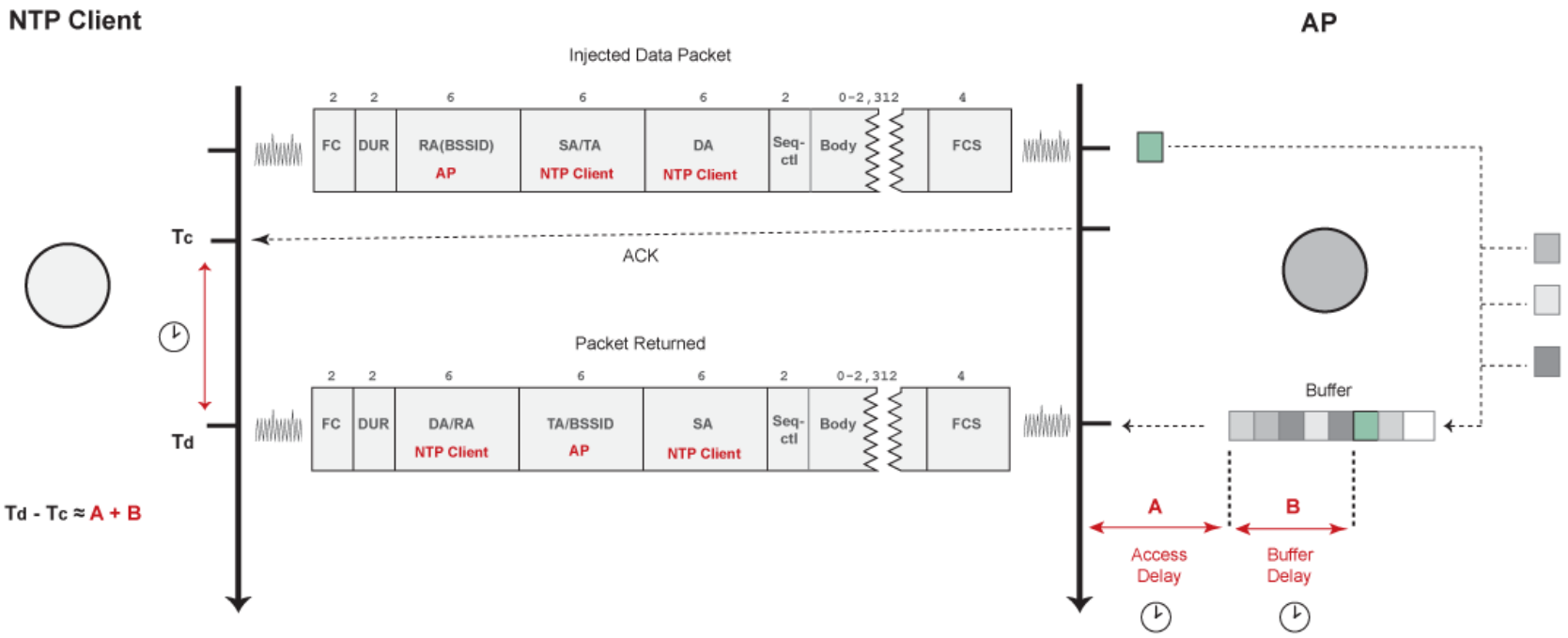
Up-link Delay (**Δu**) Determination



Down-link Delay (Δd) Estimation

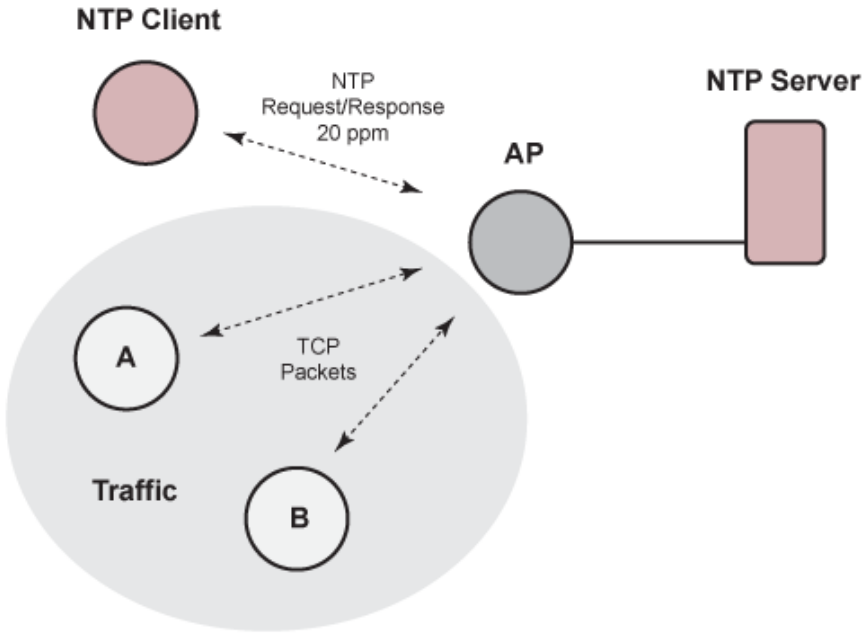


Down-Link Delay Estimation



Experiment – Real Test-Bed

- How effective is it?
- **NTP client** sends 20 NTP packets per minute
- **A** & **B** transmit TCP packets to each other via **AP**
- Create load at AP - induce large **buffer delays**
- Duration 60 mins



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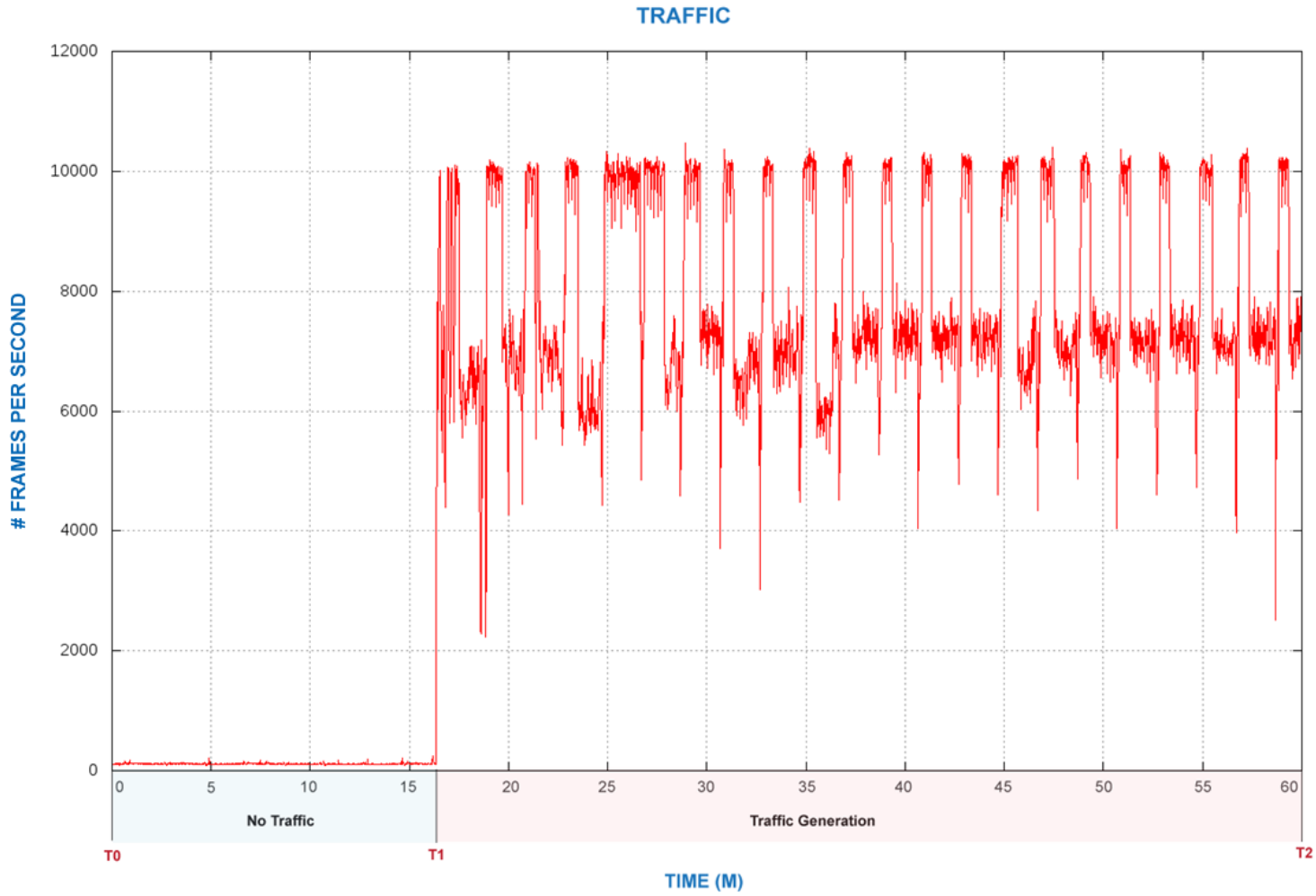
Traffic



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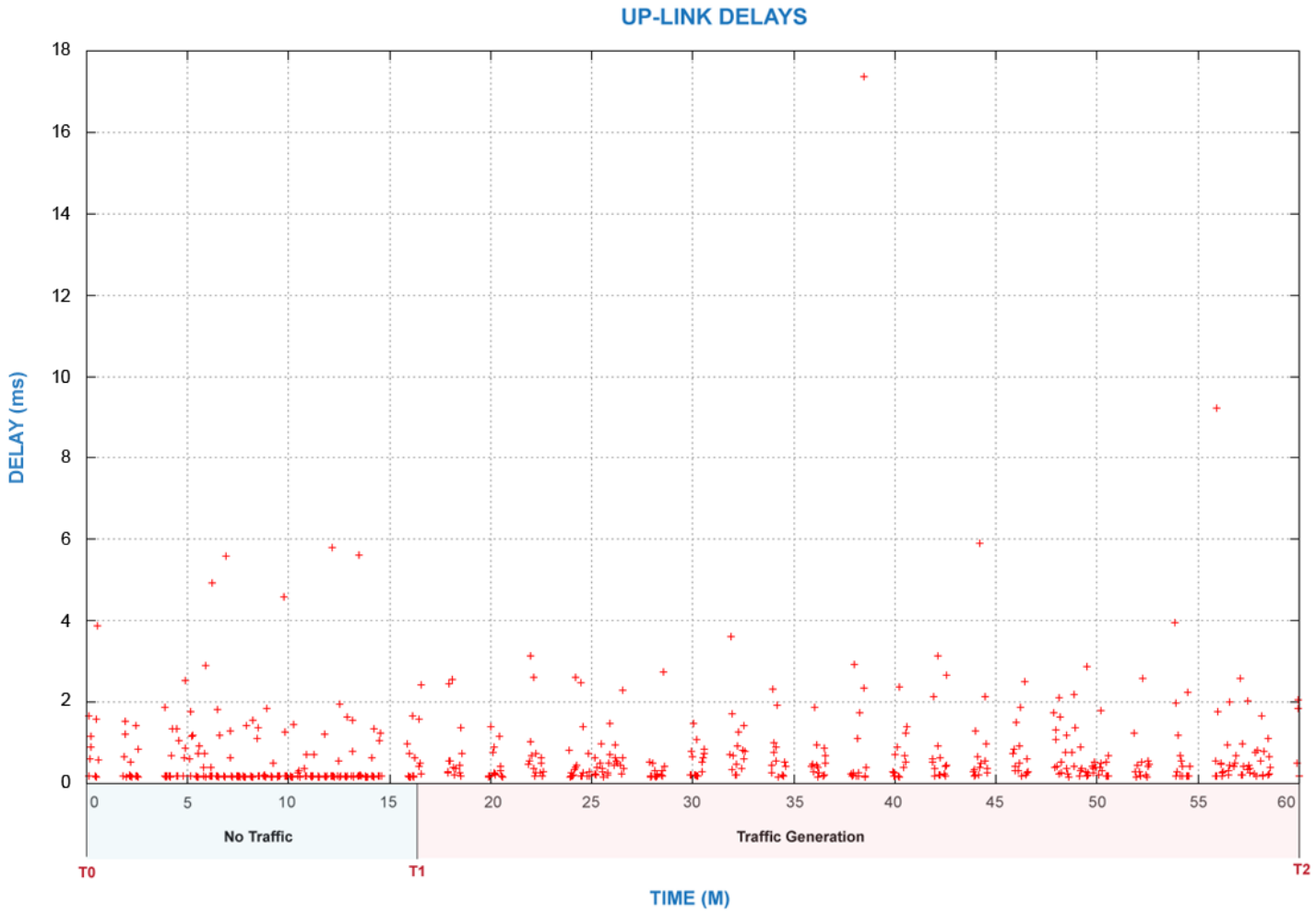
Up-Link Delays



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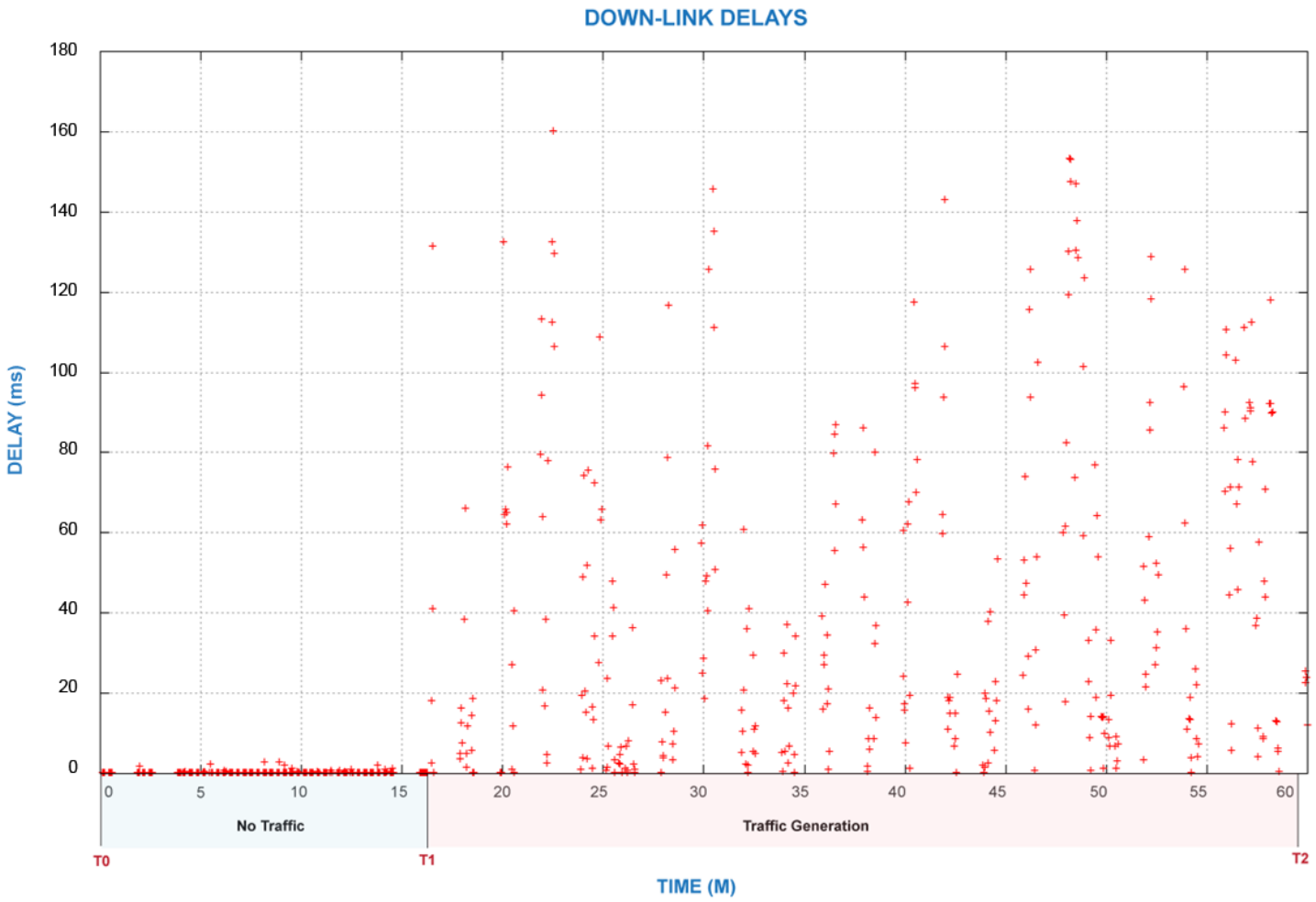
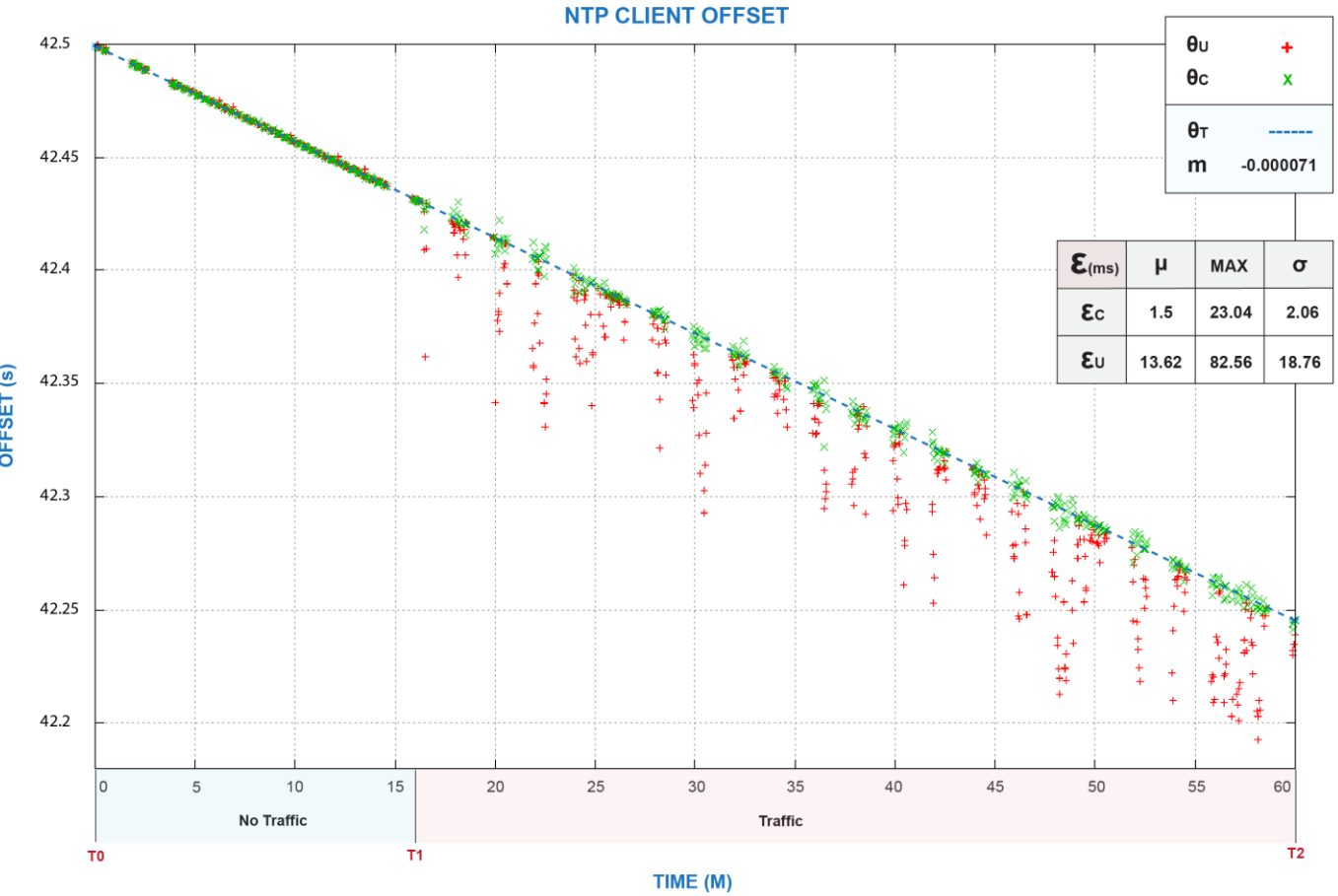
Down-Link Delays



Results – Offsets (θ) & Errors (ε)



Δ_u	up-link delay
Δ_d	down-link delay
θ_T	true offset
θ_U	un-corrected offset
θ_C	corrected offset
ε_U	un-corrected offset error
ε_C	corrected offset error

$$\theta_T = -0.000071(T_i) + 42.547466$$

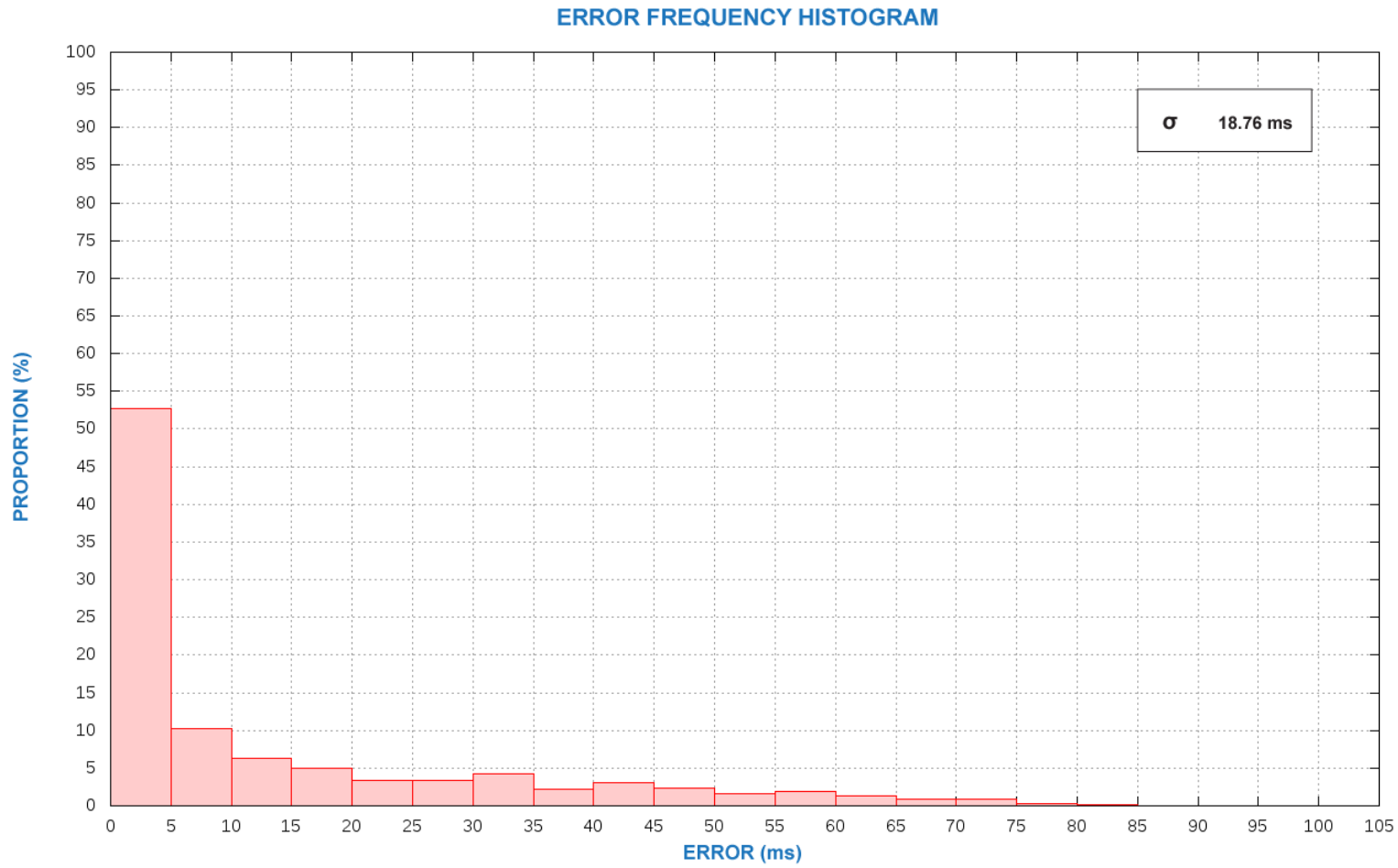
$$\theta_U = \frac{(T_{i+1} - T_i) + (T_{i+2} - T_{i+3})}{2}$$

$$\theta_C = \frac{(T_{i+1} - T_i) + (T_{i+2} - (T_{i+3} - \Delta_d + \Delta_u))}{2}$$

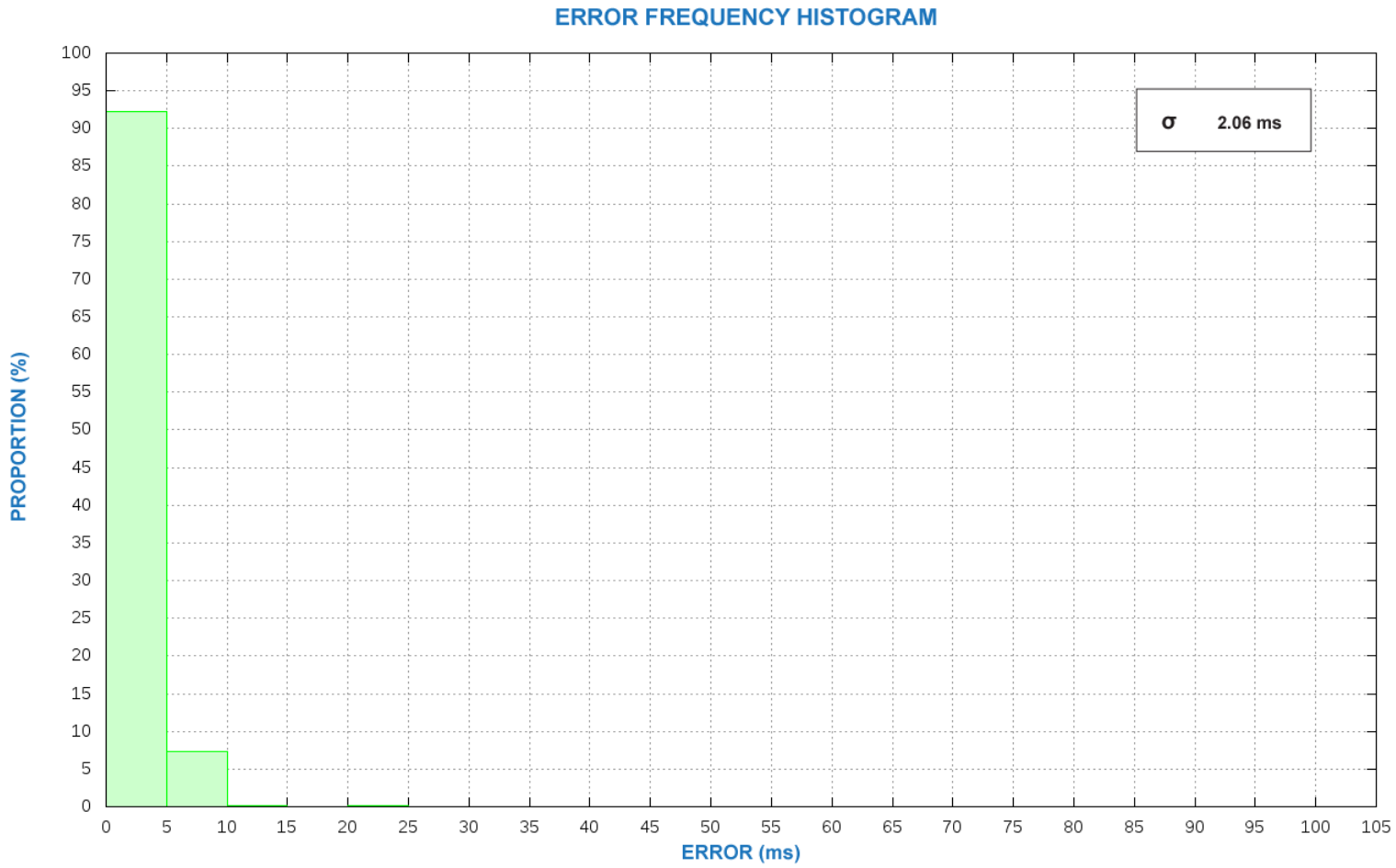
$$\varepsilon_U = |(\theta_T - \theta_U)|$$

$$\varepsilon_C = |(\theta_T - \theta_U)|$$

Error Distribution (ε_U) (un-corrected)



Error Distribution (ε_c) (corrected)



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Outcome

- **Module/Technique** – reduces synchronisation errors in 802.11 networks
- Can be used on any host with
  - Protocol that uses **uni-directional** or **round-trip** synchronisation
  - NIC that supports **packet injection**
- Results indicate up to **90% reduction** in average offset errors
- Improve quality of dataset provided to time protocols

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- P. O. Flaithearta, H. Melvin, and P. Pocta. **Time awareness in software defined networking**. European Conference on Networks and Communications, 2015.

- P. O Flaithearta, H. Melvin, and M. Schukat. **A qos enabled multimedia wifi access point.** International Journal of Network Management, 25(4):205–222, 2015.

- Y. Cinar, H. Melvin, and P. Pocta. **A black-box analysis of the extent of time-scale modification introduced by webrtc adaptive jitter buffer and its impact on listening speech quality.** Special Issue of Communications journal (Scopus) on Telecommunications Beyond, 2016.

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Questions