

CCNC 2016 - January 2016

# Coexistence of IEEE 802.11n and Licensed-Assisted Access devices using Listen-before-Talk techniques

Claudio Casetti



POLITECNICO  
DI TORINO

DET  
Department of Electronics and Telecommunications

# Introduction: LTE in unlicensed spectrum

- Development of LTE radio communications technology in unlicensed spectrum motivated by superior:
  - link performance
  - medium access control
  - mobility management
  - coverage
  - spectrum availability ( $> 400\text{MHz}$ )
- LTE Small Cells need to coexist with the Wi-Fi ecosystem



# LTE and WiFi Coexistence

- Several proposals:
  - LTE-U
    - Supplemental downlink (SDL), paired with a licensed LTE carrier, used in carrier-aggregation mode (*LTE-U Forum*) - does not require LBT (Listen Before Talk)
  - LTE-LAA
    - LBT MAC-layer operations based on Clear Channel Assessment (*3GPP-ETSI*) in 5GHz band
      - Frame-based Equipment (FBE)
      - Load-based Equipment (LBE)

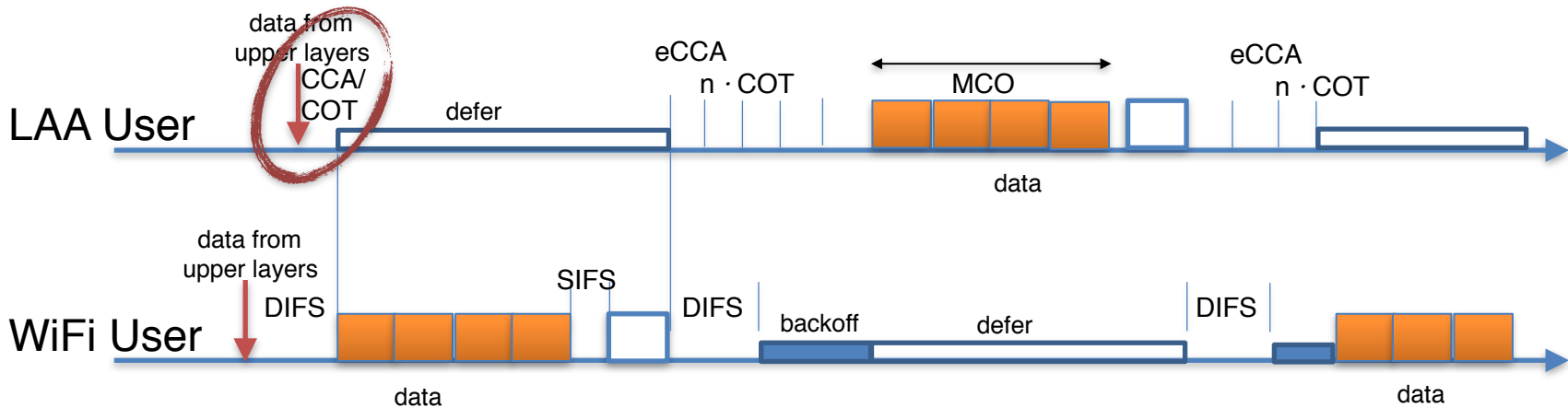


# Regulations for FBE/LBE devices

- Limitations on transmission power (23 dBm in Europe and 24 dBm in the U.S. for indoor usage)
- Interference-avoidance mechanisms toward incumbent systems by using Dynamic Frequency Selection (DFS)
- Listen Before Talk (LBT) MAC-layer operations for graceful coexistence with the contention-based WiFi DCF protocol



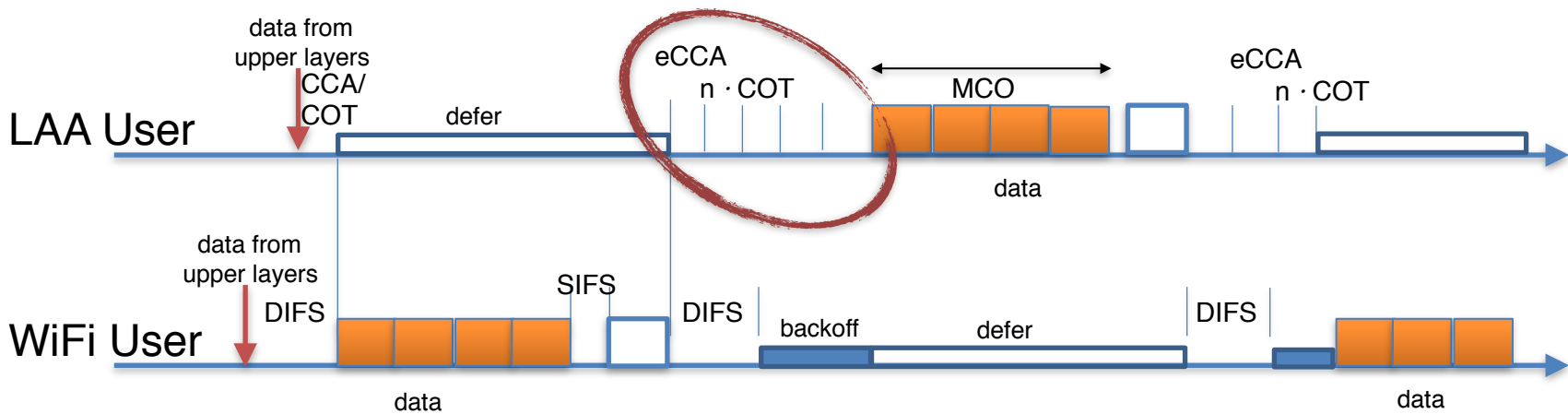
# MAC guidelines for LBE-LAA



- Any transmission by LBE must be preceded by a Clear Channel Assessment (CCA)
  - The channel is observed for at least  $20 \mu\text{s}$  (Channel Observation Time, COT)



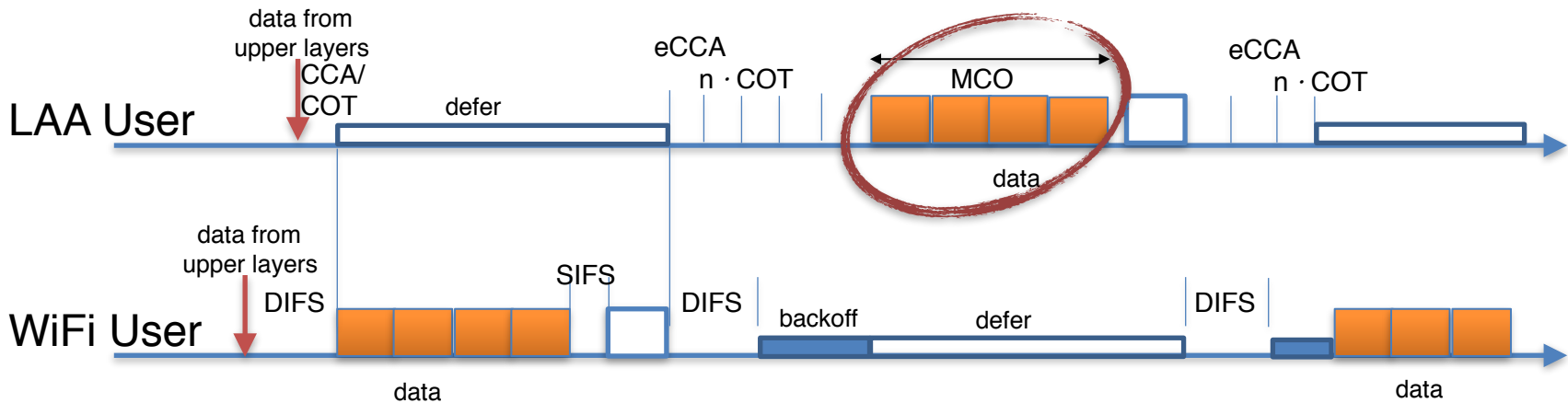
# MAC guidelines for LBE-LAA



- If the channel is found occupied, an Extended CCA (eCCA) check is performed
  - the channel is monitored for a time  $n \cdot COT$ ,  $n \in [1, q]$ ,  $q \in [4, 32]$



# MAC guidelines for LBE-LAA



- Transmission by an LBE must not last for more than a Maximum Channel Occupancy (MCO) time
  - MCO determined as  $13/32 \cdot q$  ms



# Differences between DCF/EDCA and LAA MAC

- EDCA backoff and eCCA ranges differ depending on the implementation, the version of 802.11 and the choice of Access Category
- eCCA does not increase exponentially
- The random values in LAA eCCA do not include 0
- The choice of the  $q$  parameter is critical:
  - small  $q$  shortens the wait before channel capture by LAA
  - small  $q$  shortens the maximum channel occupancy by LAA
  - ...and viceversa

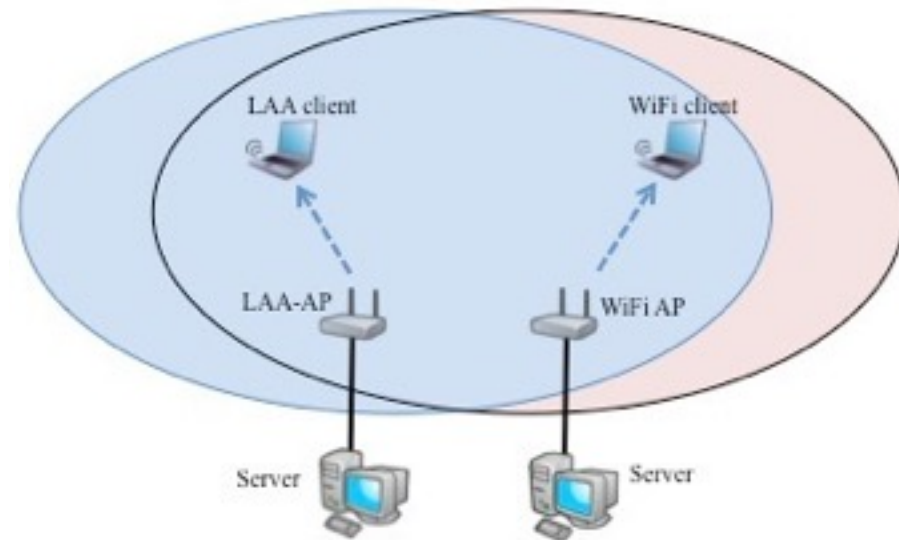




# Simulation Scenario

- LAA and 802.11n MAC implemented in OMNET++ for frame-level simulation
- Topology: single-cell heterogeneous residential network
  - overlapping LAA and WiFi APs coverages, contending for the channel
  - LAA and WiFi clients, exchanging traffic with outside server
- Traffic: two flow types sent in different 802.11n Access Categories
  - downlink UDP with exponentially-distributed intergeneration time
  - On-Off VoIP traffic

PHY/MAC Parameters	Value
PHY data bitrate	135 Mb/s
PHY basic bitrate	13 Mb/s
PHY control bitrate	135 Mb/s
802.11 MAC Slot Time	9 $\mu$ s
LAA MAC COT	20 $\mu$ s
802.11/LAA MAC retry limit	7 $\mu$ s
LAA $q$ parameter	8, 32 $\mu$ s
802.11 MAC A-MPDU max size	65535 B
802.11 MAC MPDU spacing	8 $\mu$ s



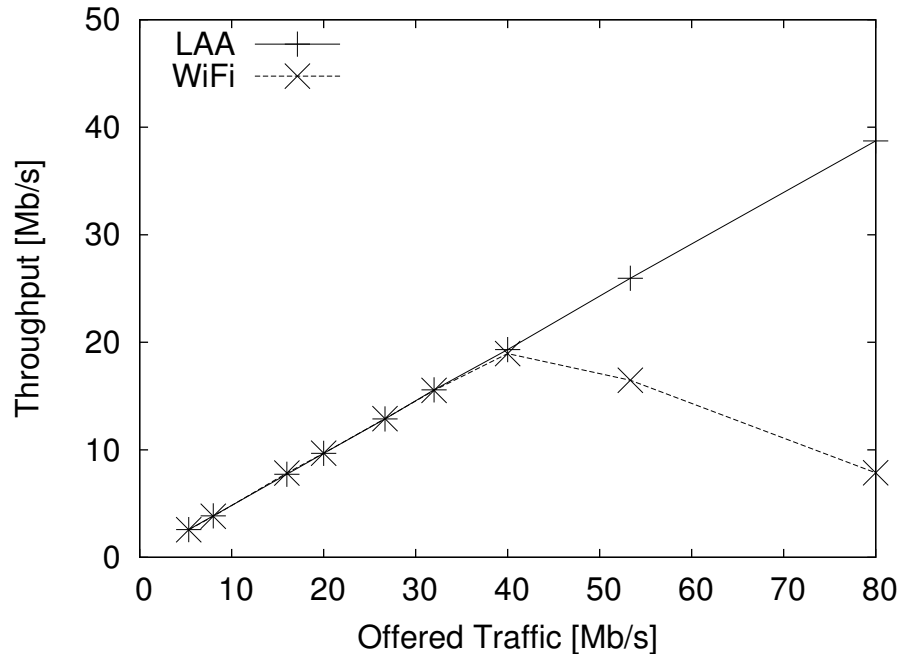
# Metrics of interest

- *Throughput*: the average of the number of packets correctly received, divided by the simulated interval
- *Frames per MCO*: average number of frames transmitted by the LAA-AP during the MCO
- *Subframes per A-MDPU*: average number of subframes aggregated into an A-MPDU by the WiFi AP
- *End-to-end delay and jitter*: average packet delivery delay and jitter measured at the application layer
- Results are collected with and without 802.11n frame aggregation

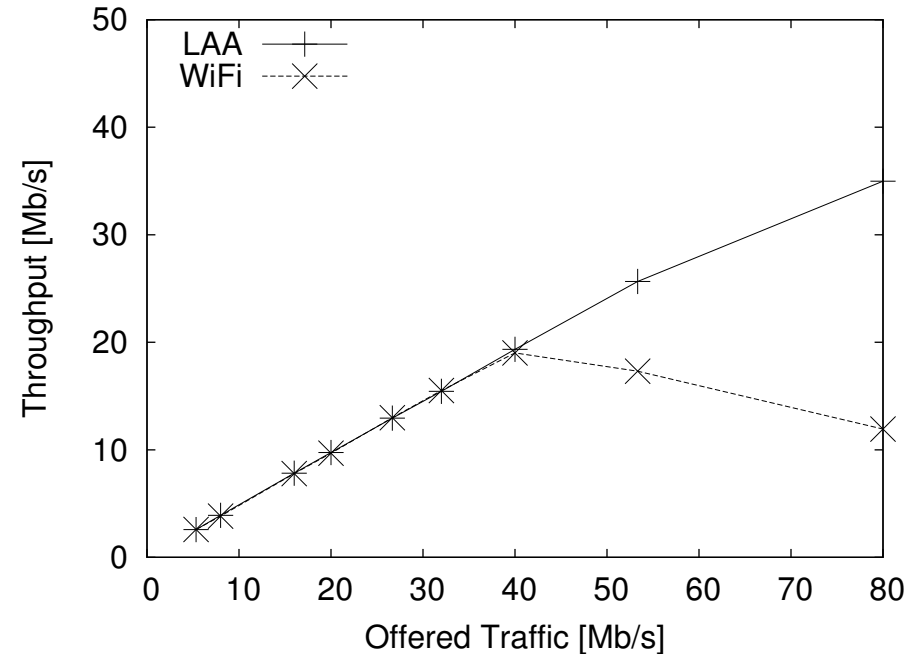


# No frame aggregation - UDP traffic

q=8



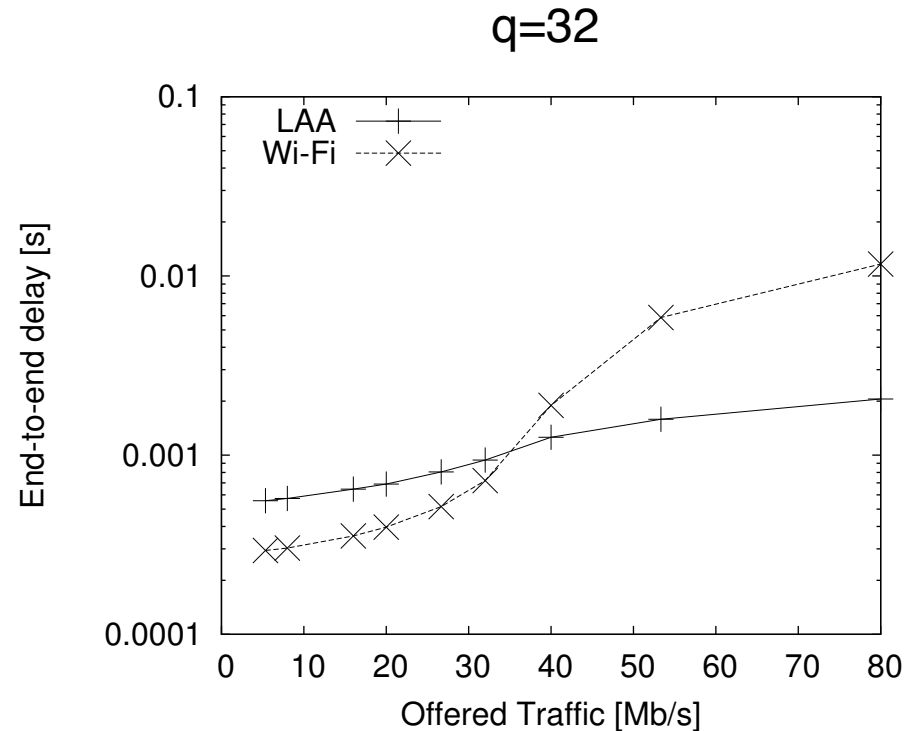
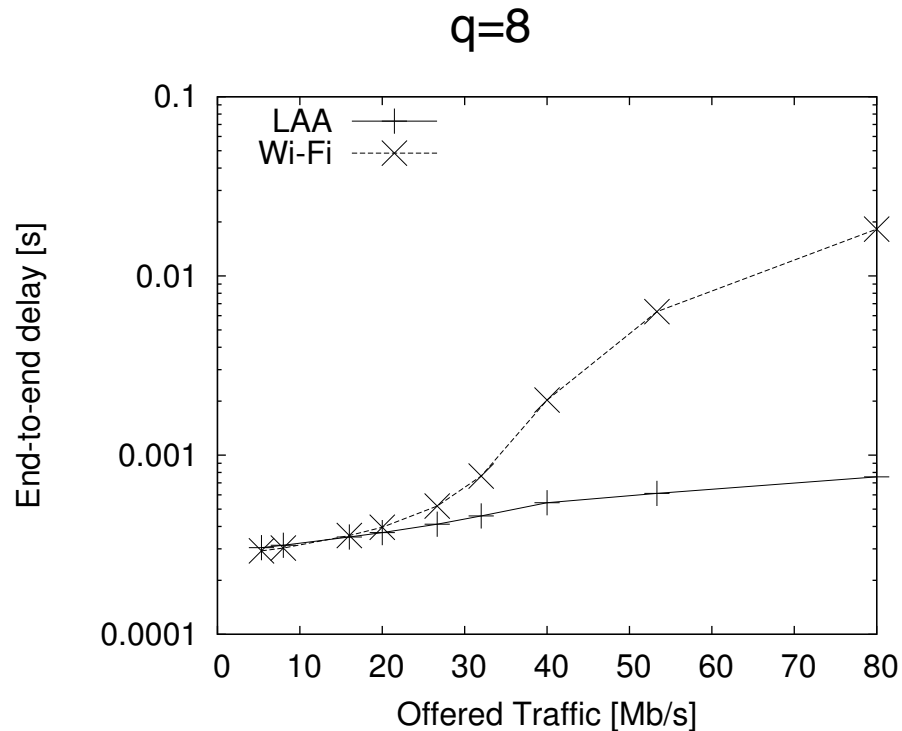
q=32



WiFi traffic sent as AC BE without MPDU aggregation



# No frame aggregation - UDP traffic

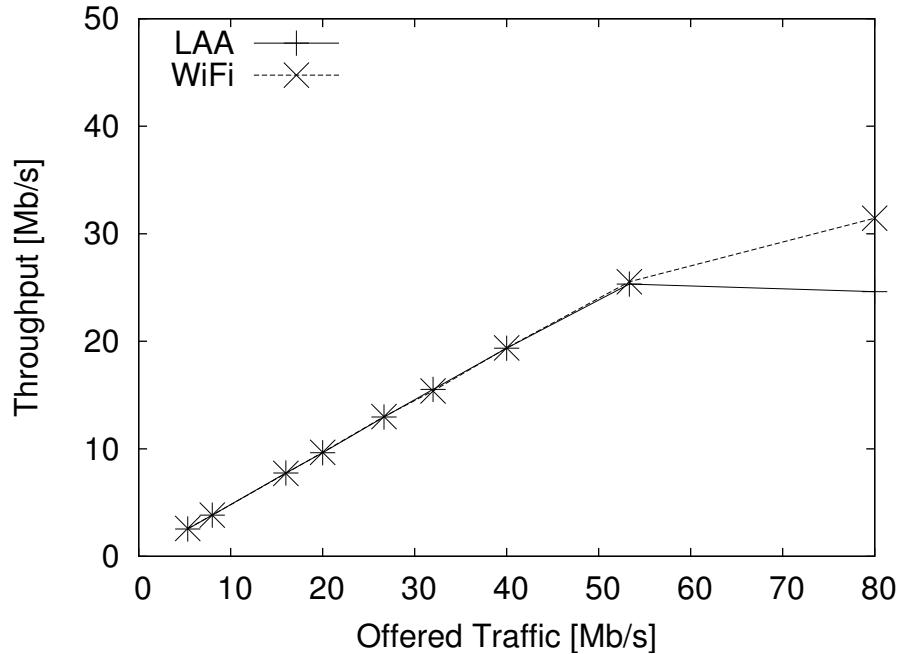


WiFi traffic sent as AC BE without MPDU aggregation

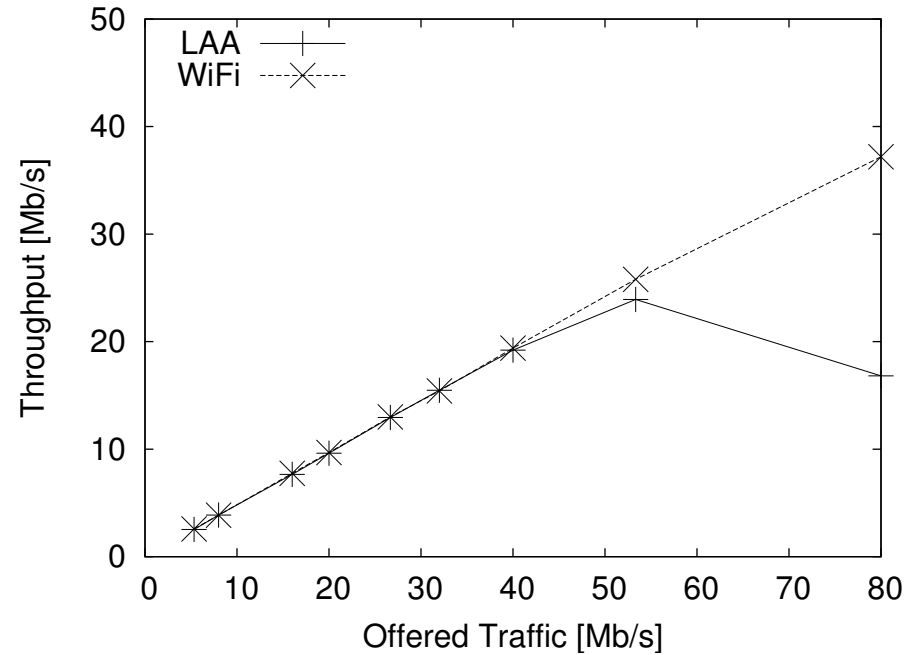


# No frame aggregation - UDP traffic

q=8



q=32



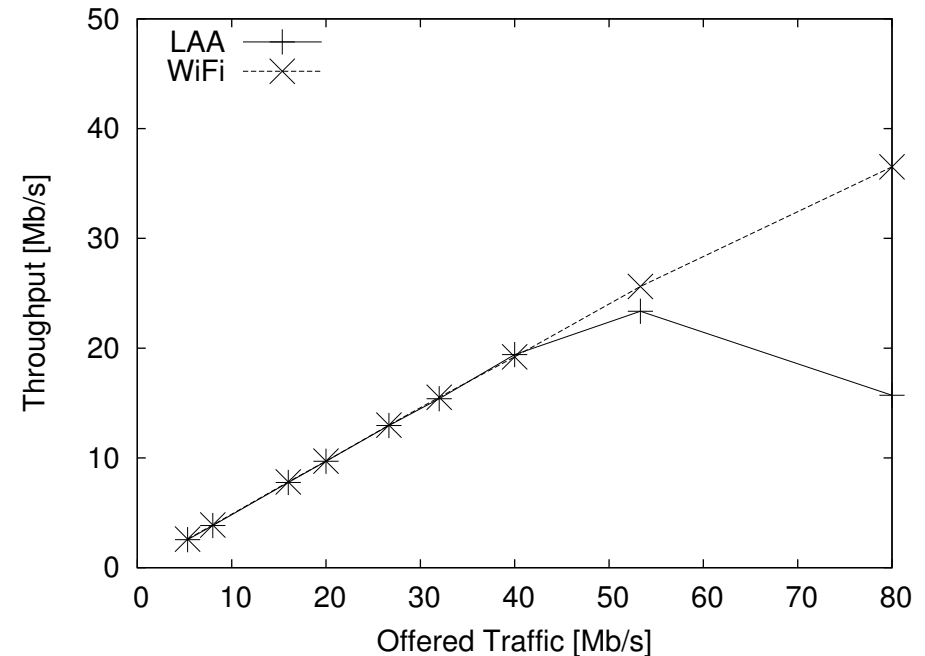
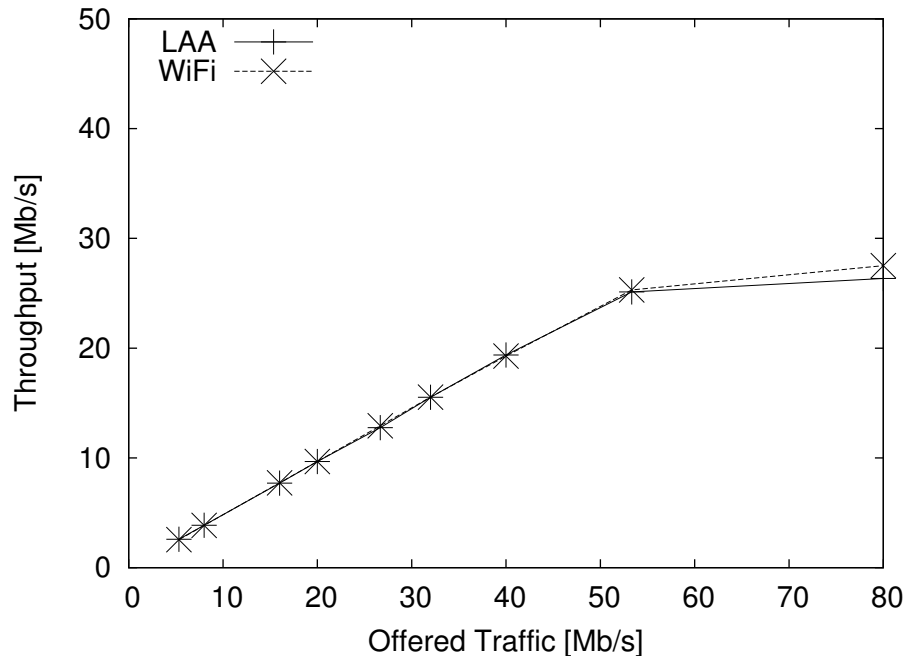
WiFi traffic sent as AC VI without MPDU aggregation



# Frame aggregation - UDP traffic

q=8

q=32

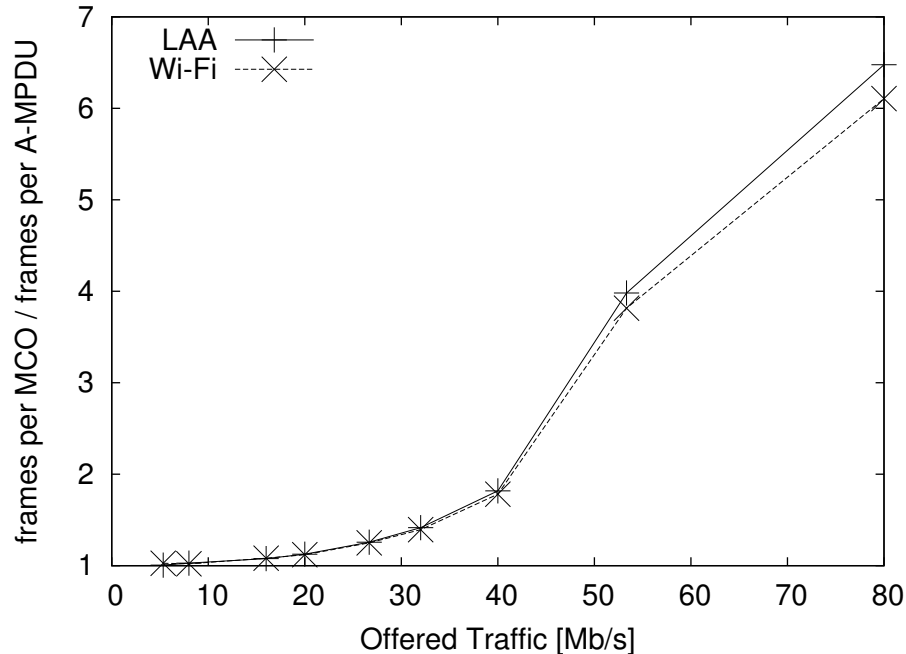


WiFi traffic sent as AC BE with MPDU aggregation

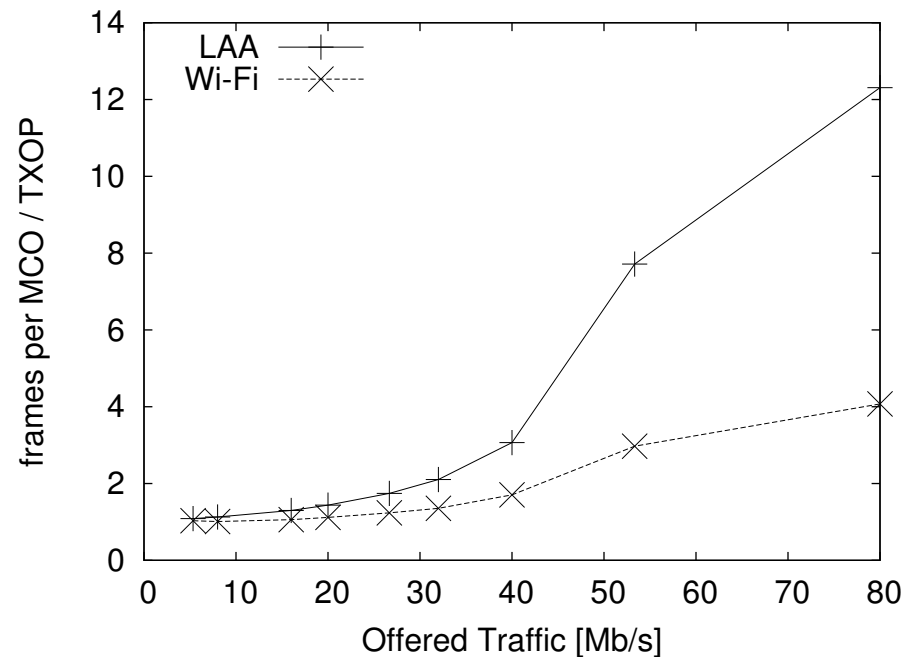


# Frame aggregation - UDP traffic

q=8



q=32

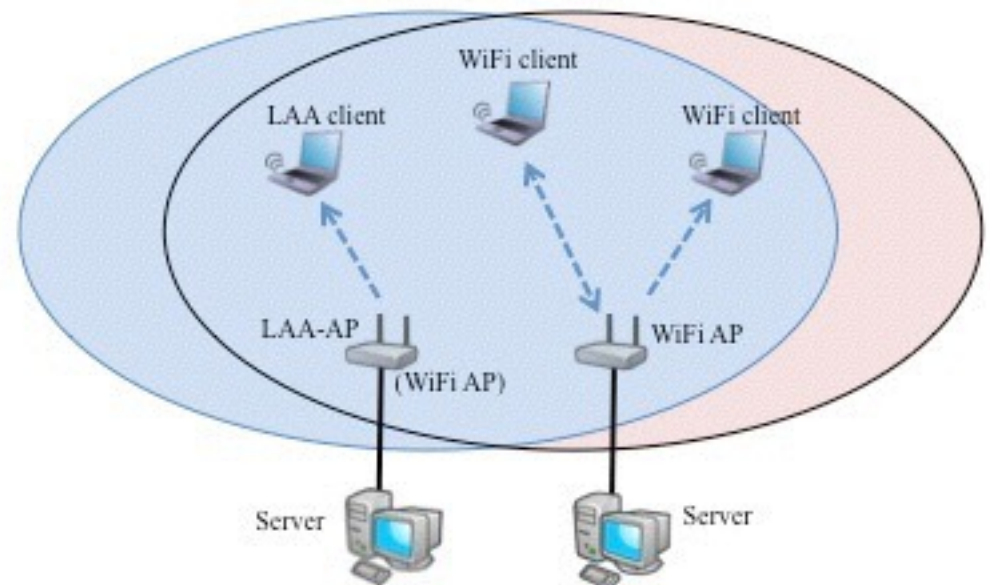


WiFi traffic sent as AC BE with MPDU aggregation



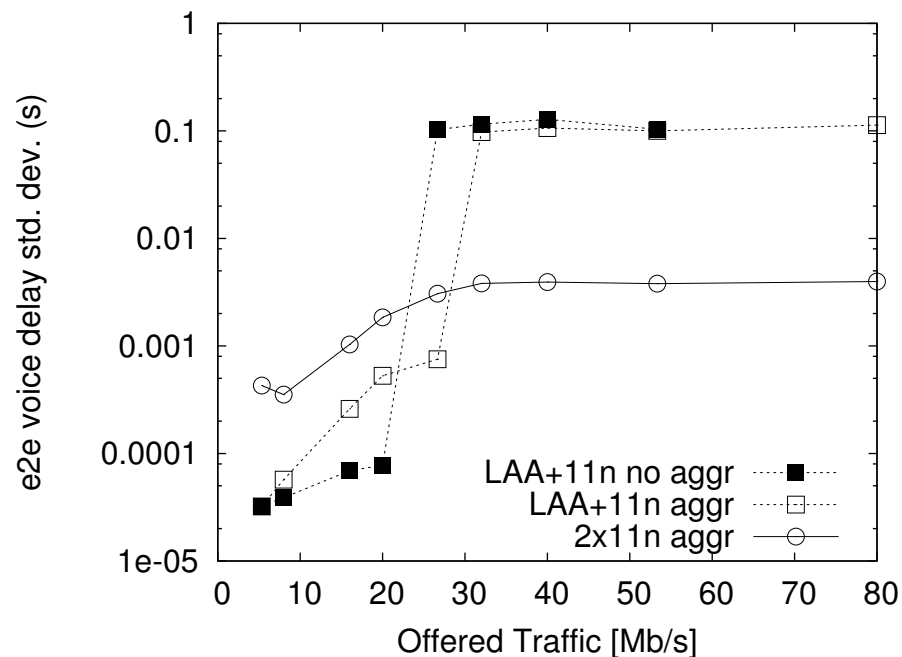
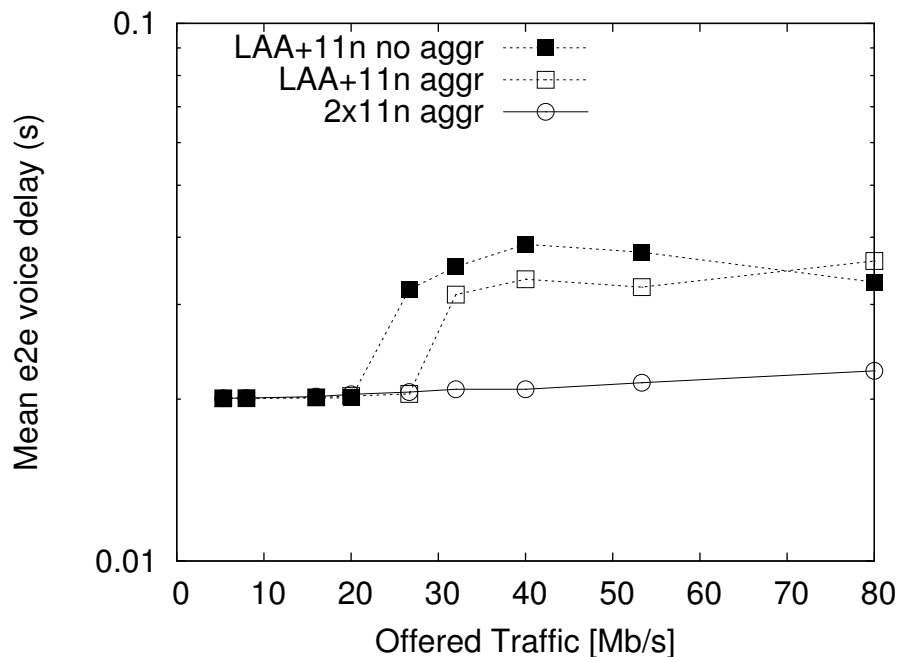
# VoIP traffic

- Additional WiFi Client sending uplink On-Off VoIP traffic in AC\_VO category
- VoIP traffic competes with UDP downlink transmitted by:
  - 1 LAA-AP + 1 WiFi AP
  - 2 WiFi AP





# VoIP traffic



VoIP traffic sent as AC VO (LAA using  $q=8$ )



# Conclusions

- WiFi 802.11n fairly competes against LAA at high loads
  - if WiFi traffic is sent in higher Access Categories
  - if frame aggregation is enabled
- VoIP traffic
  - can be unaffected at low-medium loads if protected by the AC VO category
  - delay jitter increase for extended MCO interval by LAA traffic
- Behaviors at high loads depend on the choice of the  $q$  parameter

