Dynamic Cross-Layer Association in 802.11-based Mesh Networks

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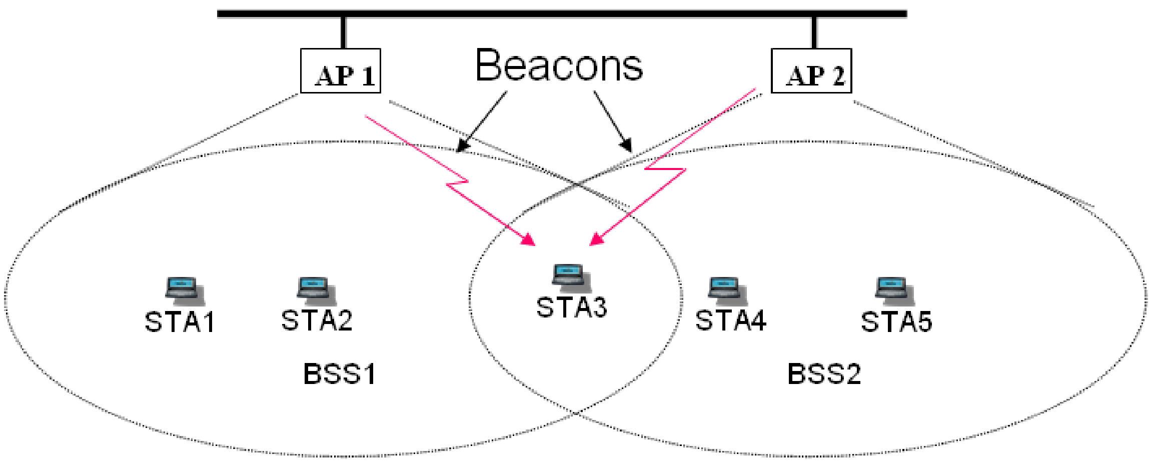
User Association in 802.11 Wireless Networks

- Scanning phase
  - Passive scanning
  - Active scanning
- Decision phase
- Association phase



- **Association decision →** Received Signal Strength (RSSRI) of the Beacons or Probe Requests sent by APs

User Association in 802.11 Wireless Networks

- **Main problem in this mechanism:**
  - RSSRI is not an appropriate decision factor for user association (high RSSRI values cannot univocally indicate high throughput)
    - RSSRI not only depends on the distance from the APs, but also on the transmission powers of the APs
    - RSSRI is an indicator for the downlink but not for the uplink channel conditions
    - Throughput depends on the population of the cell served by the APs

Airtime Metric for STA Association

- **Airtime metric* →** represents the average duration for which the channel is occupied by a transmission
- Airtime cost of station $i \in U_\alpha$ where U_a is the set of stations associated with AP a:

$$C_a^i = \left[O_{ca} + O_p + \frac{B_t}{r^i}\right] \frac{1}{1 - e_{pt}^i}$$

O_{ca} is the channel access overhead, O_p is the protocol overhead and B_t is the number of bits in the test frame. The input parameters r_i and e_{pt} are the bit rate in Mbs, and the frame error rate for the test frame size B_t

*Introduced by 802.11s as a routing decision metric

Airtime Metric for STA Association

- Load on the “uplink” channel of a particular AP a:

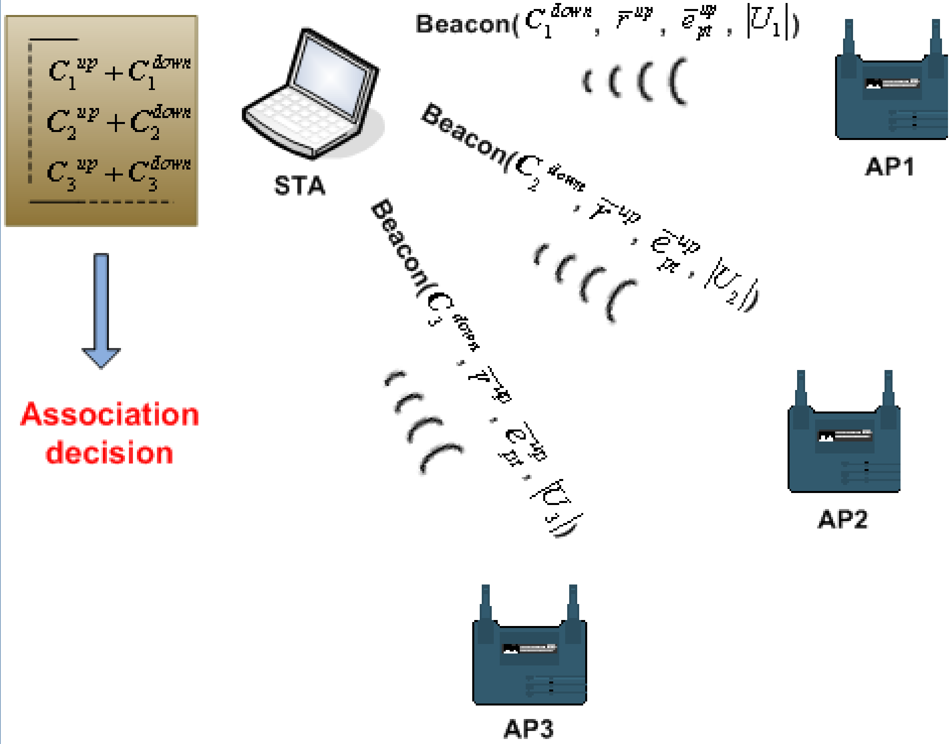
$$C_a^{up} = \left[O_{ca} + O_p + B_t \overline{(1/r^{up})}\right] \frac{1}{1 - \overline{e_{pt}^{up}}} |U_a|$$

where $\overline{e}_{pt}^{up}$, r^{up} and $|U_a|$ are the average uplink error probability, average uplink transmission rate and the number of STA associated with AP a

- Load on the “downlink” channel of a particular AP a:

$$C_a^{down} = [O_{ca} + O_p] \sum_{j \in U_a} \frac{1}{1 - e_{pt}^j} + B_t \sum_{j \in U_a} \frac{1}{r^j (1 - e_{pt}^j)}$$

Execution of the Airtime Mechanism



Load on the "uplink" channel

+

Load on the "downlink" channel

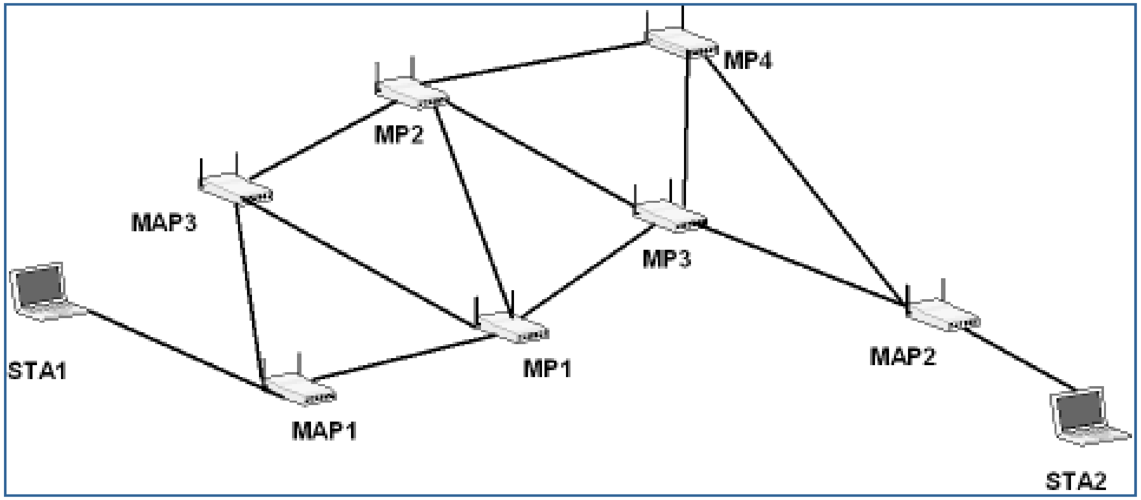
↓

Total association cost

↓

Association decision

Cross-Layer Association Mechanism



- We extend the previous scheme by considering the end-to-end QoS that each user faces
- End-to-end QoS → incorporated in the association process of a station with a MAP
- RM-AODV (Radio Metric Ad-Hoc On Demand Distance Vector) introduces the airtime link cost as a routing decision metric

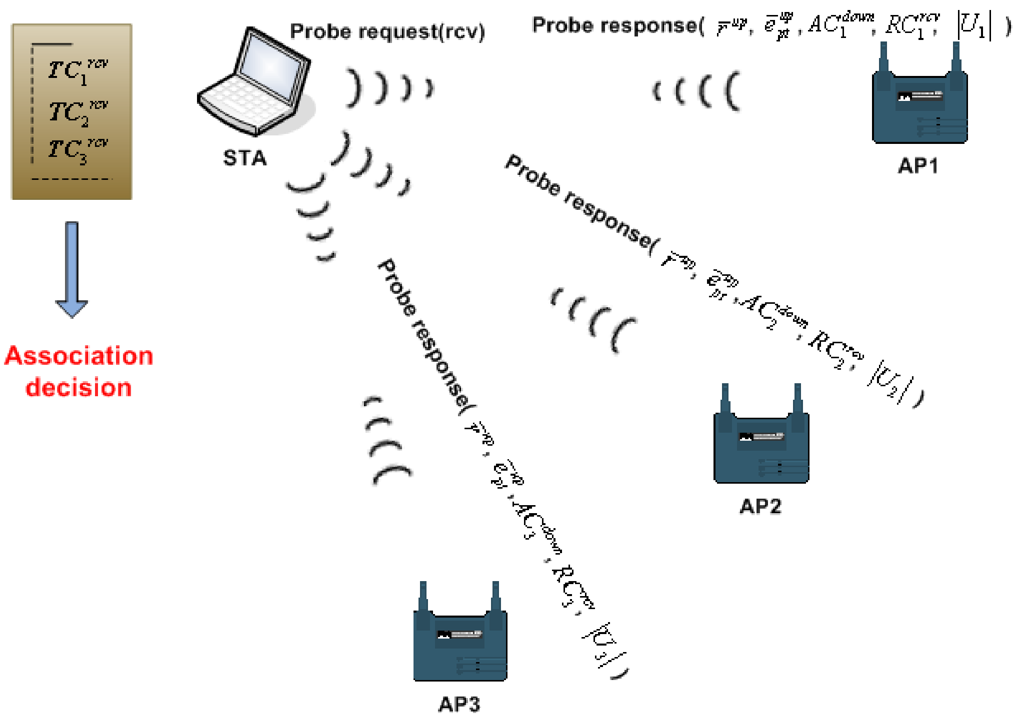
Cross-Layer Association Mechanism

- The association airtime cost and the routing airtime cost are weighted by the station that initiated the association scanning:

$$TC_i^{rcv} = (AC_i^{up} + AC_i^{down})w_1 + RC_i^{rcv} w_2$$

where TC_i^{rcv} is the total weighted cost calculated for MAP *i*, AC_i^{down}, AC_i^{up} are the association airtime costs for the uplink and downlink respectively (we used symbol C before) , RC_i^{rcv} is the routing airtime cost for the path from MAP *i* to the receiver *rcv* and w_1, w_2 are the weights

Execution of the Cross-Layer Mechanism



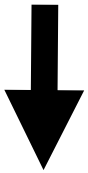
Load on the “uplink” channel

+

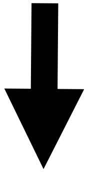
Load on the “downlink” channel

+

Routing airtime cost



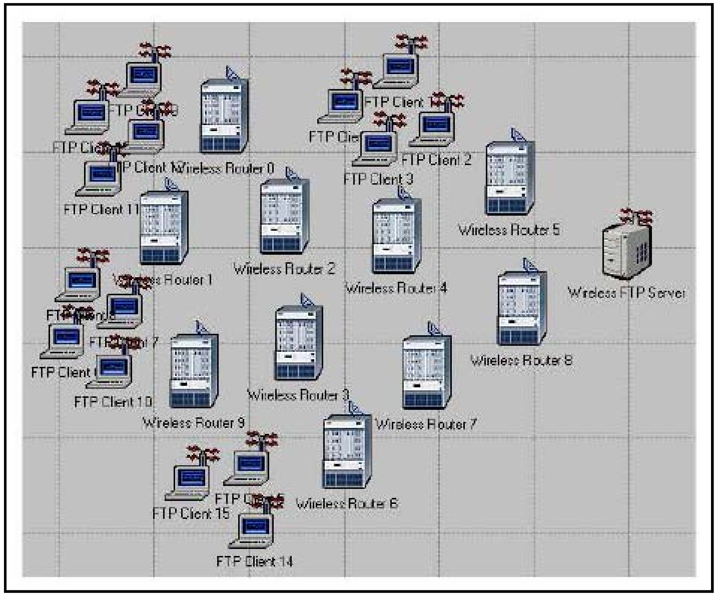
Total cost



Association decision

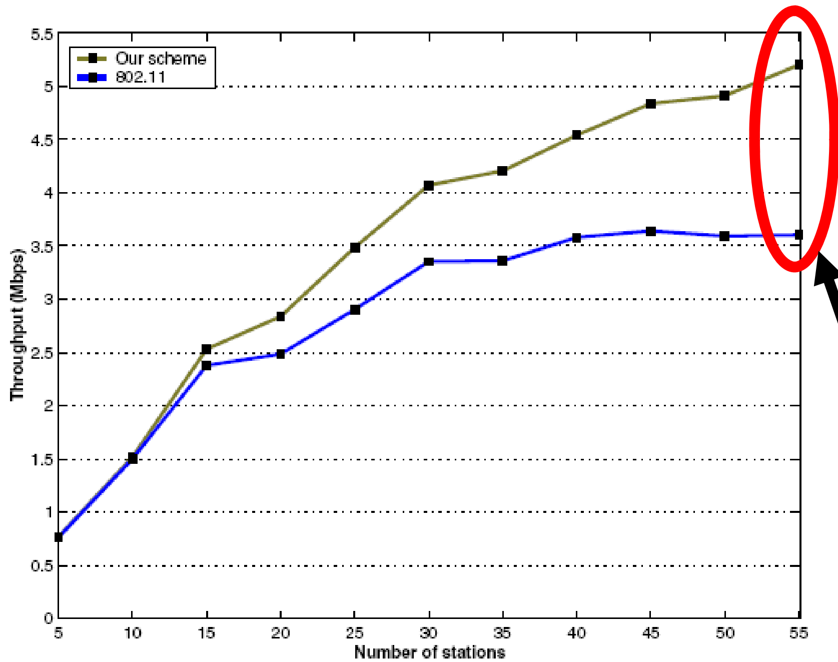
Mechanisms Evaluation

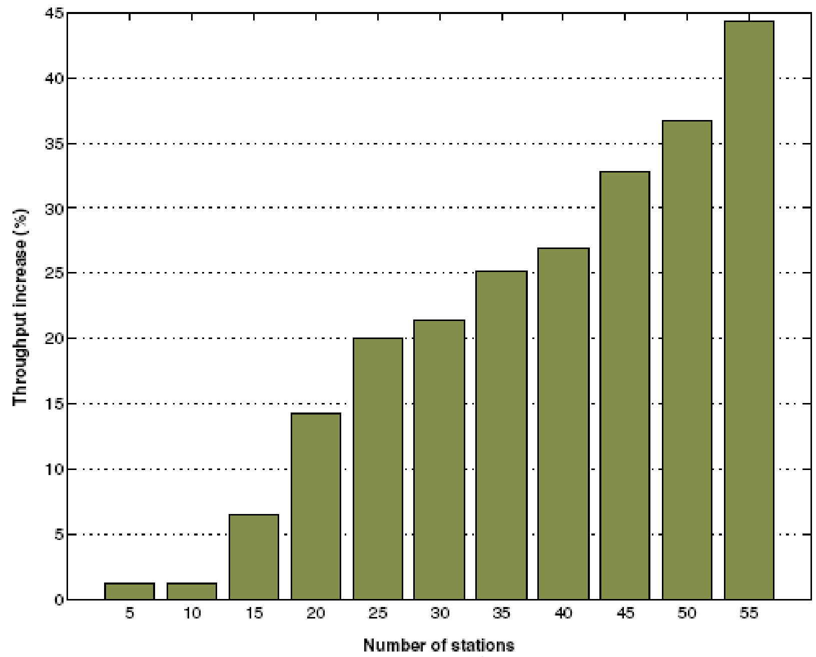
- Simulation environment: OPNET
- Multi-cell 802.11 scenario (Airtime Association Scheme)
  - Overlapping cells
  - STAs are uniformly distributed
- Mesh scenario (Cross-Layer Association Scheme)



Mechanisms Evaluation

- Simulation results for the airtime association mechanism (multi-cell scenario)

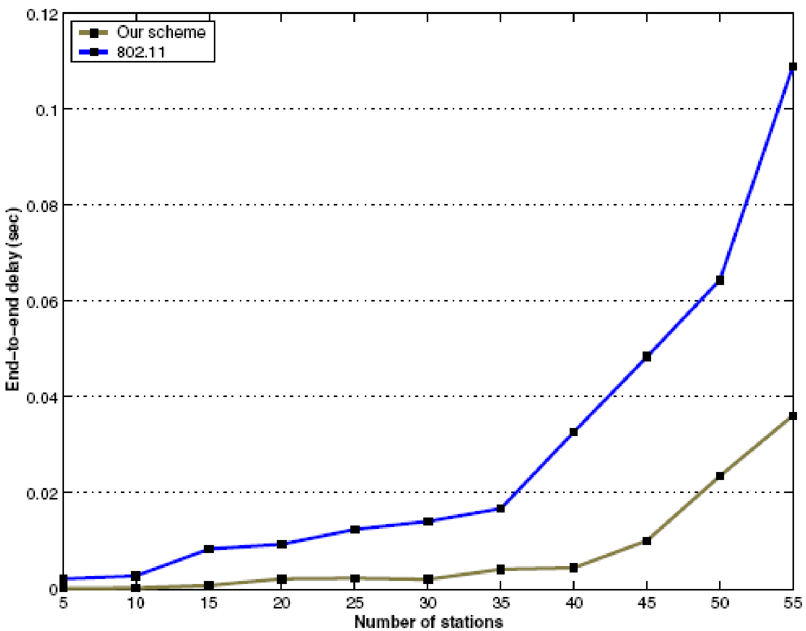


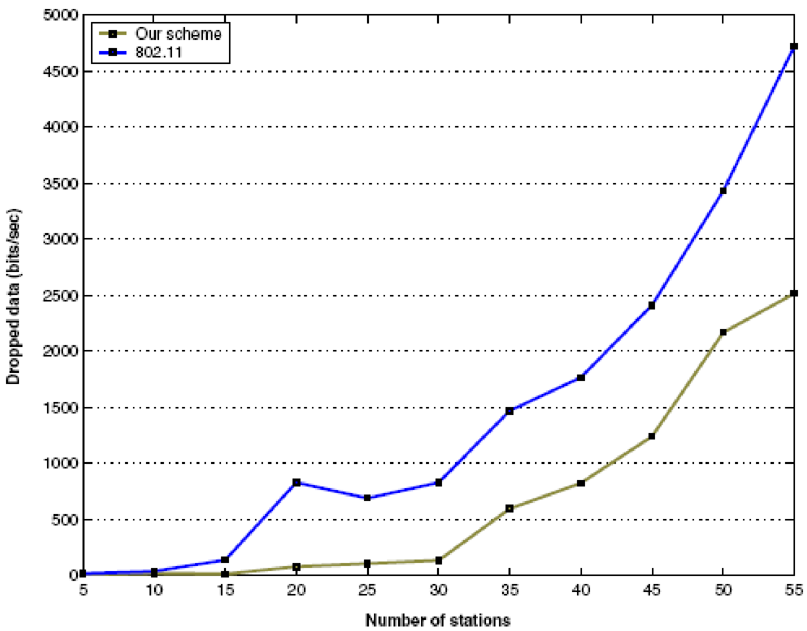


44% throughput increase

Mechanisms Evaluation

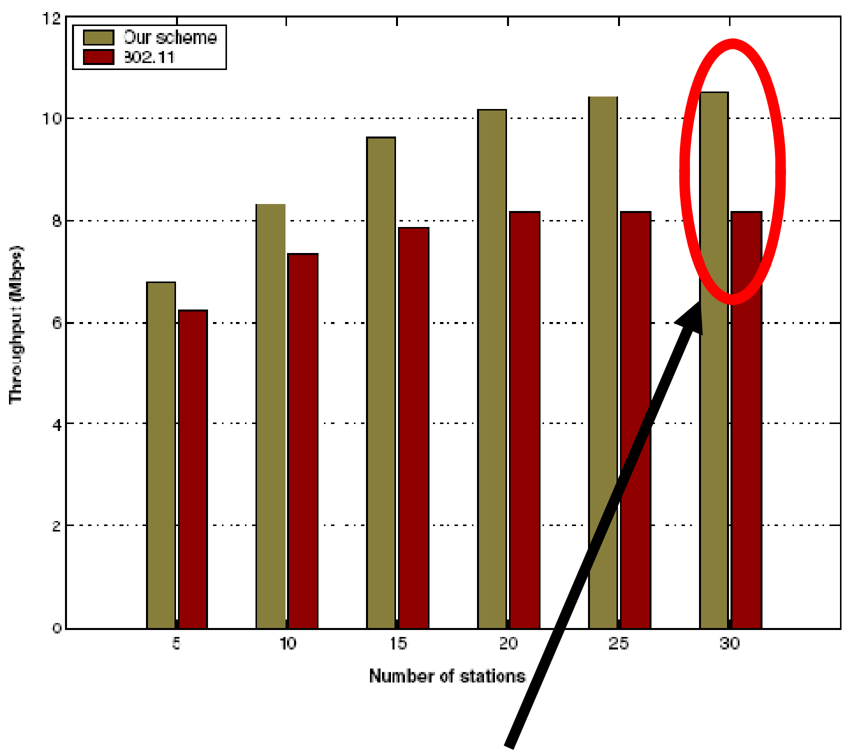
- Simulation results for the airtime association mechanism (multi-cell scenario)



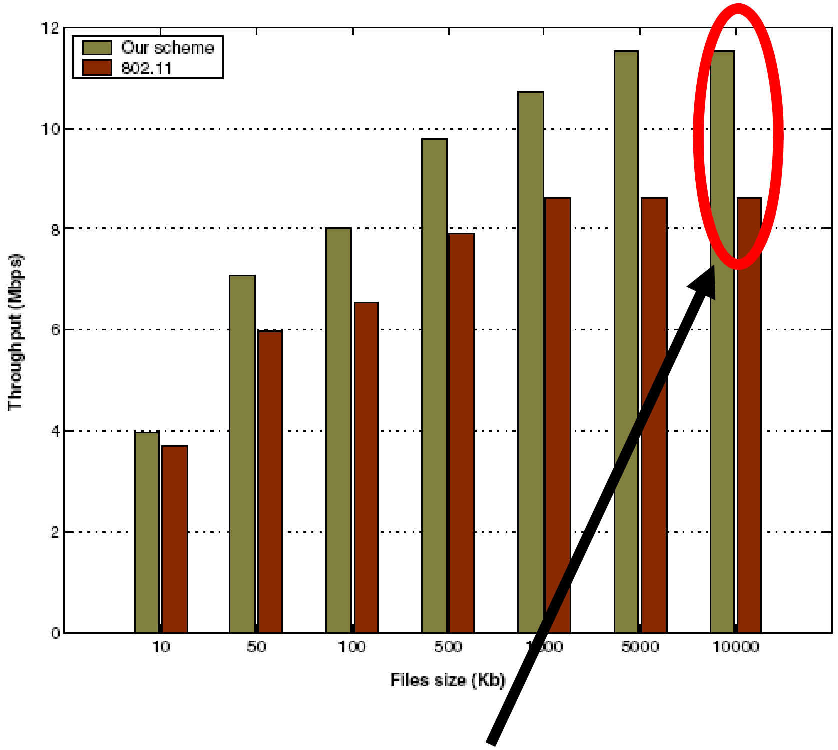


Mechanisms Evaluation

- Simulation results for the cross-layer association mechanism (Mesh scenario - FTP)



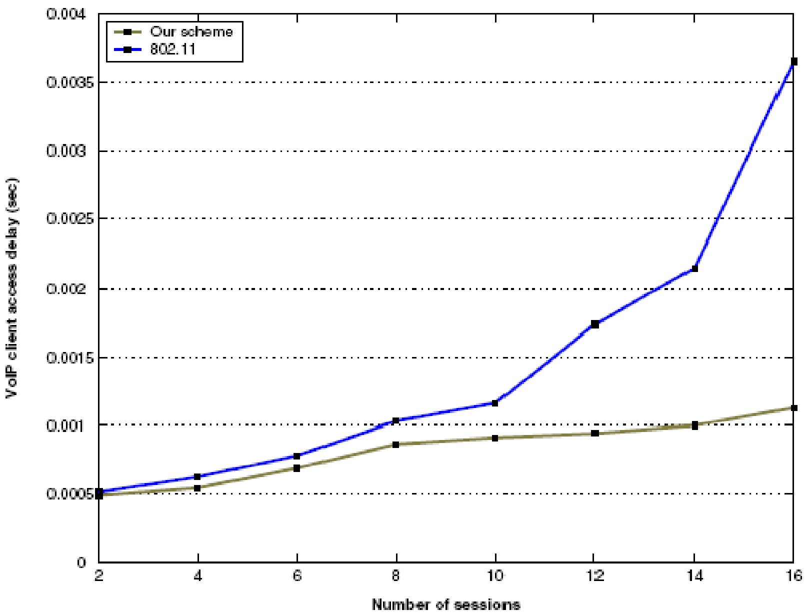
28% throughput increase

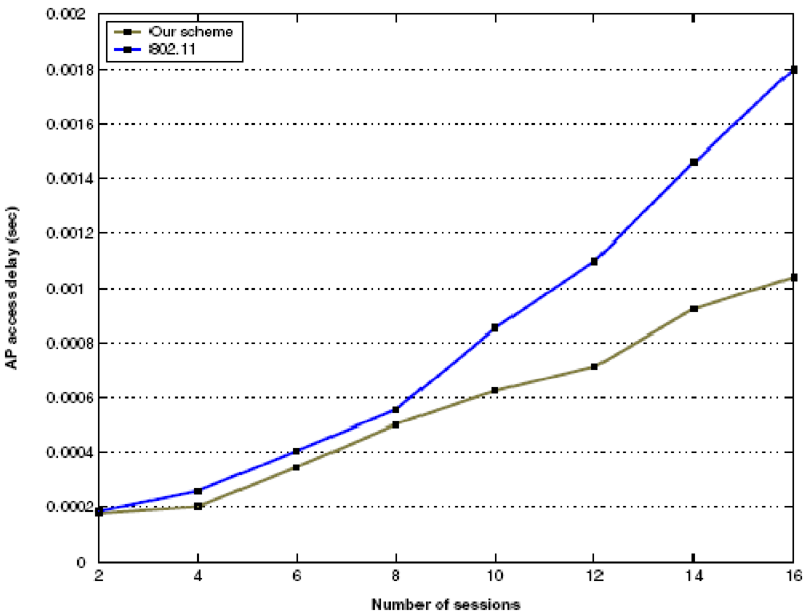


33% throughput increase

Mechanisms Evaluation

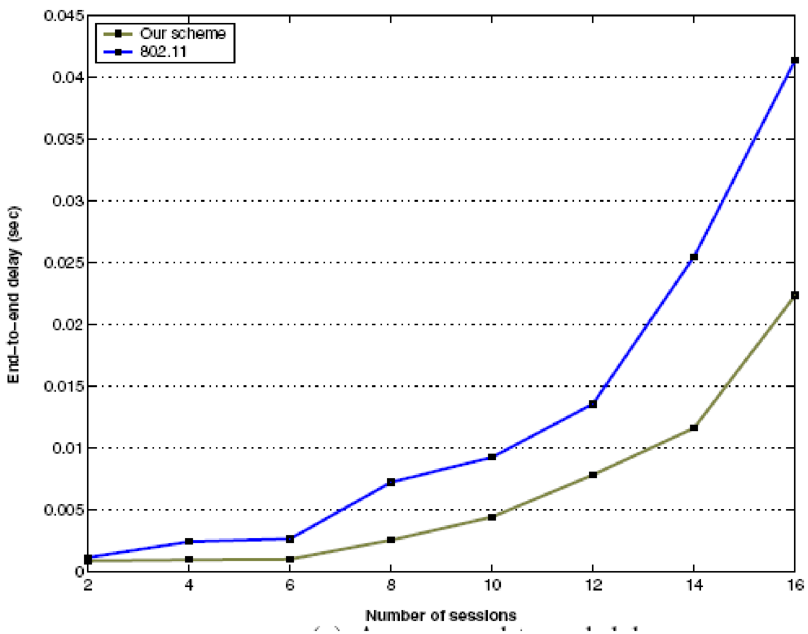
- Simulation results for the cross-layer association mechanism (VoIP)

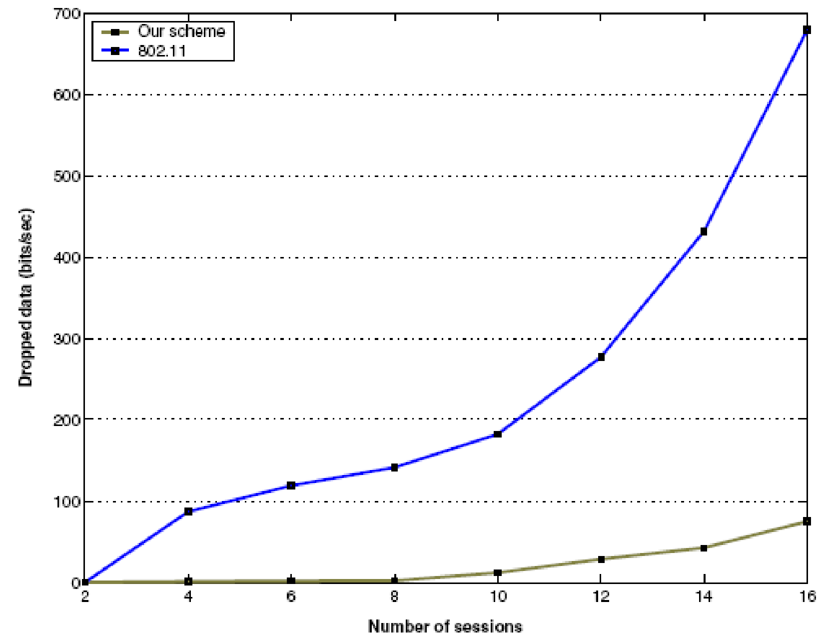




Mechanisms Evaluation

- Simulation results for the cross-layer association mechanism (VoIP)





Testbed @ CERTH

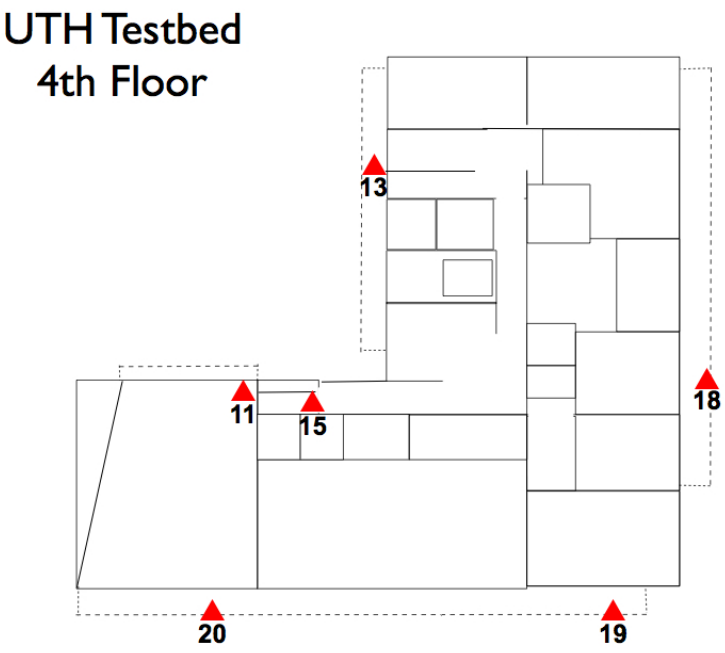
- Linux server
  - The server provides
    - NFS support for mounting the OS
    - Access to the OMF ORBIT management system
- 9 ORBIT nodes deployed (http://www.orbit-lab.org)
  - They mount a Debian Linux over NFS, kernel v2.6
  - 2 Wireless cards, Atheros, chipset: AR5212, MadWifi driver
  - 1 GHz VIA C3 CPU, 512 MB RAM, 40 GB HDD, 2 IEEE 802.11 a/b/g cards
  - … many more nodes to be deployed
- Switch:10/100 D-Link Ethernet switch, 24 ports, PoE.

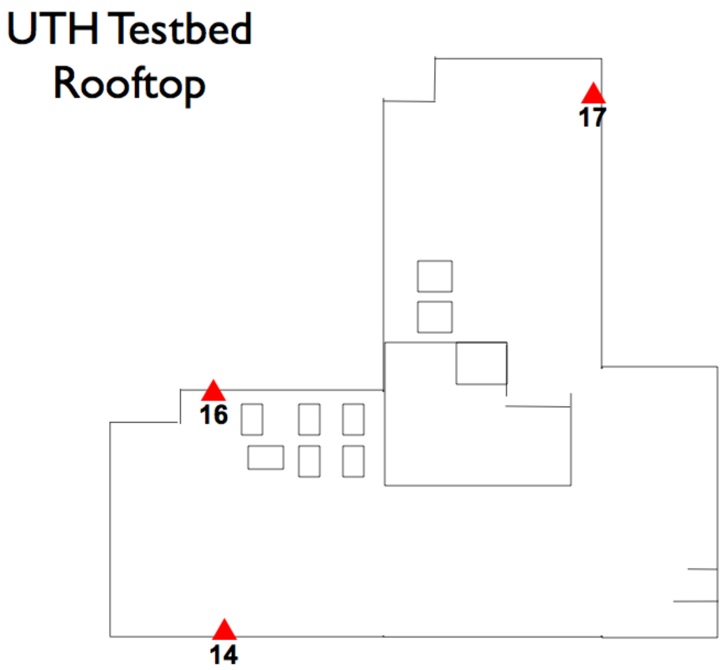
Testbed @ CERTH

- Outdoor and indoor nodes
- Spans 2 floors of our campus building
- We have deployed our own cabling infrastructure
  - For both power and Ethernet
  - Cables are protected by a plastic cover (tube)
- Outdoor nodes are placed inside waterproof plastic boxes
- We can remotely power them on/off

Testbed @ CERTH

- Topology





Testbed @ CERTH

- Nodes

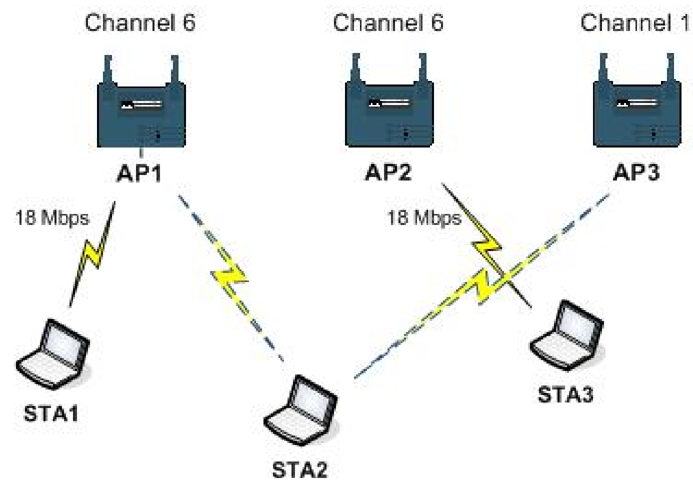
Mechanism implementation

- MADWIFI (Multiband Atheros Driver for Wireless Fidelity) driver
- Open source linux kernel device driver for Wireless LAN chipsets
- Implements most of the 802.11 MAC functionalities and therefore it is easy to modify the driver code in order to change parameters, or implement new features.
- Implement custom made protocols by making light changes in the current 802.11 implementation

Open source driver support

- Pros
  - Linux based
  - Open source drivers: modification of the MAC layer
  - Implementation of MAC/Network cross layer algorithms
  - 802.11 cards: implementation is backward compatible with current WiFi products
  - The performance of the implemented protocols can be directly compared with the commercial 802.11 solutions
- Cons
  - Fixed PHY layer

Evaluation

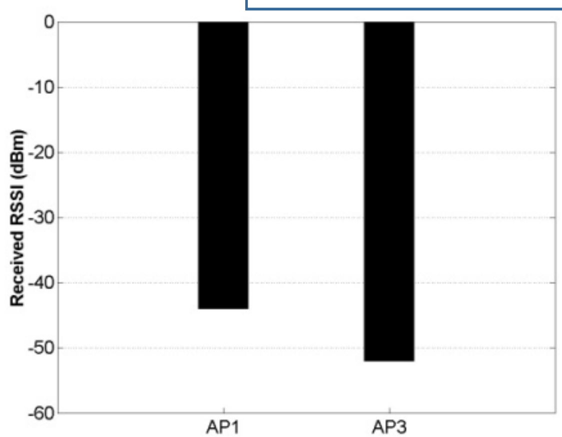


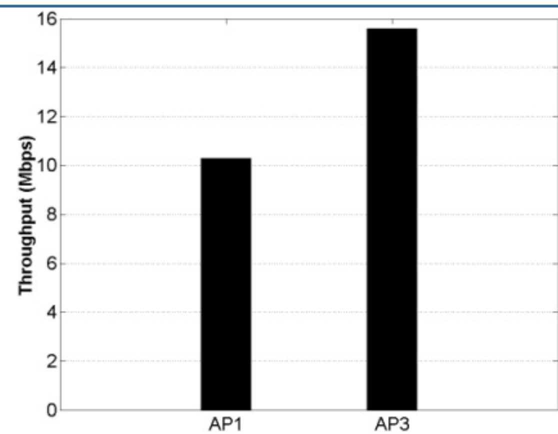
Association decision for STA2 (between AP1 and AP3):

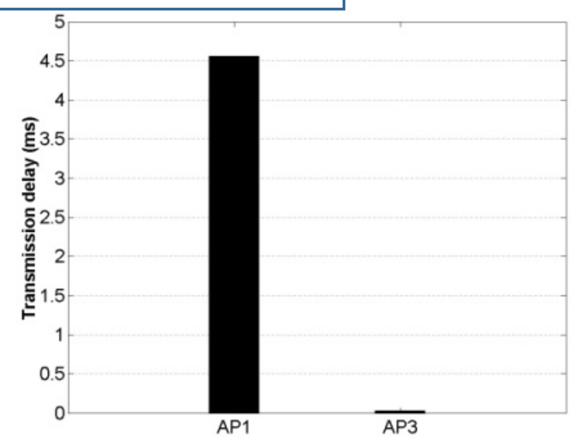
1) *802.11 (RSSI): AP1*
2) *Cross-layer Association (Airtime metric): AP3*

⇒ *Best AP for association: AP3*

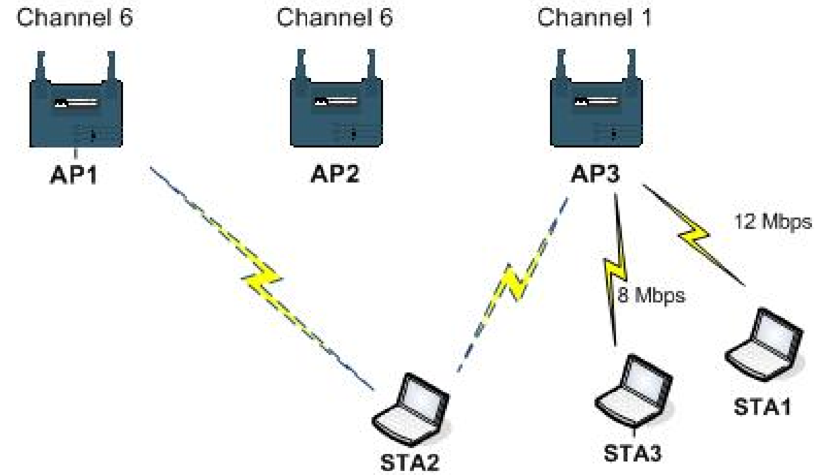
Throughput improvement: 52%







Evaluation

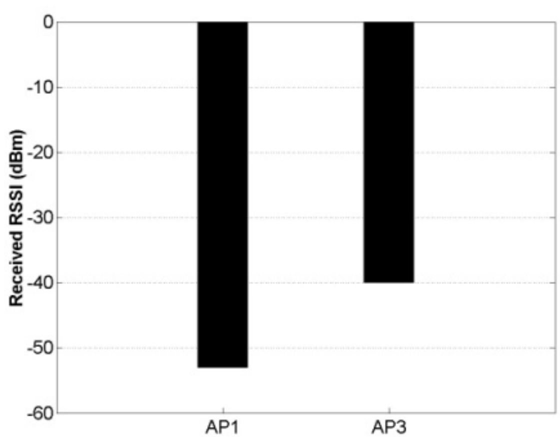


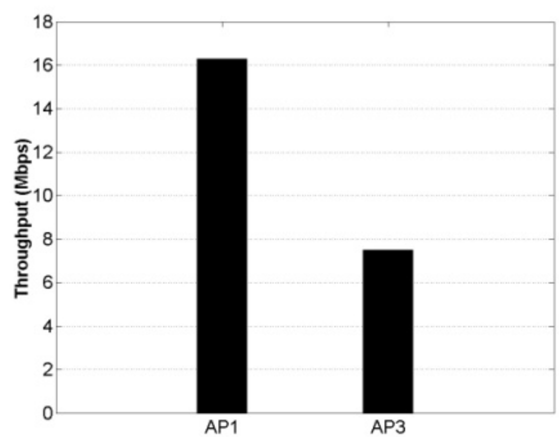
Association decision for STA2 (between AP1 and AP3):

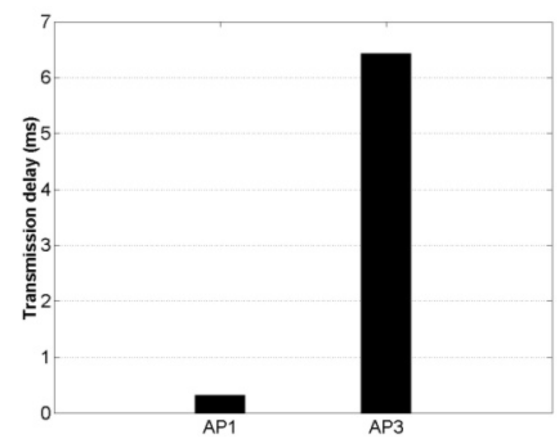
1) *802.11 (RSSI): AP3*
2) *Cross-layer Association (Airtime metric): AP1*

⇒ *Best AP for association: AP1*

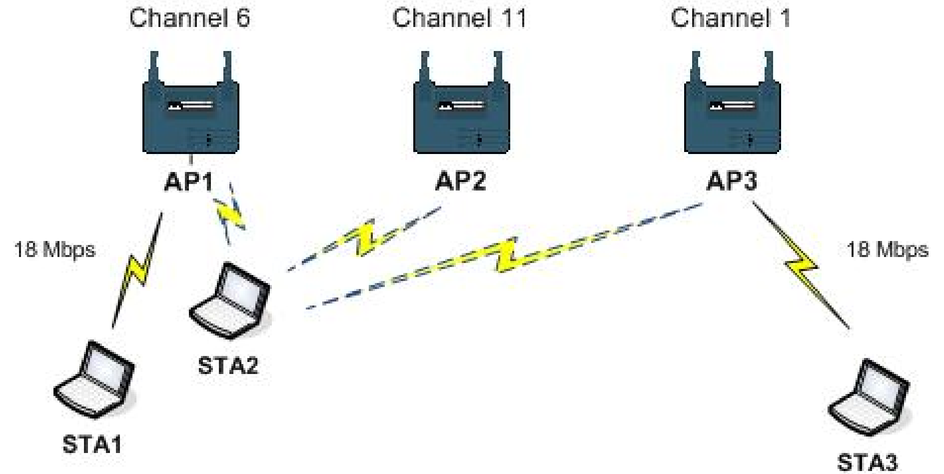
Throughput improvement: 118%







Evaluation

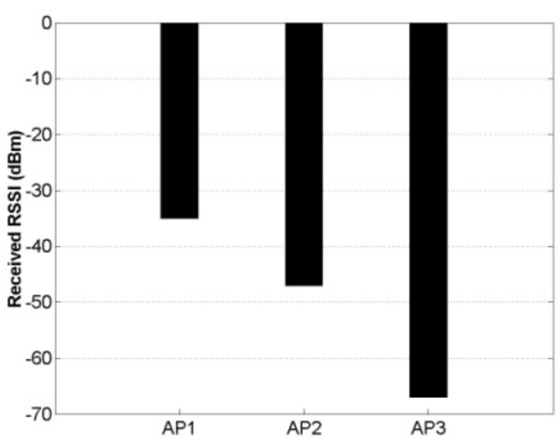


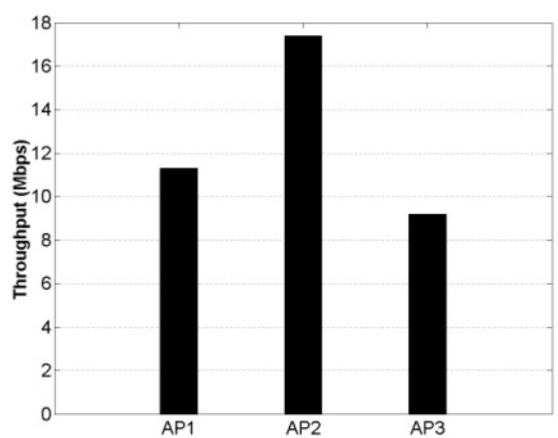
Association decision for STA2 (between AP1, AP2 and AP3):

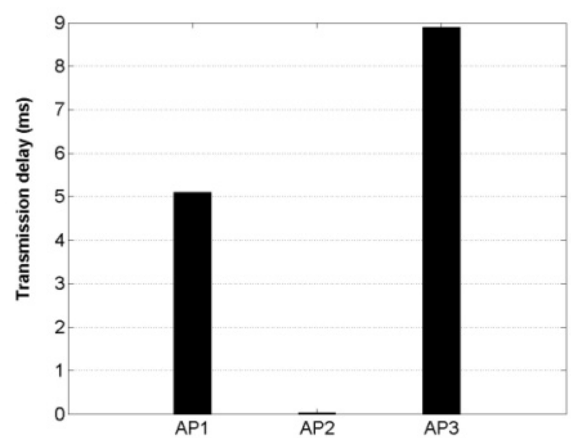
1) *802.11 (RSSI): AP1*
2) *Cross-layer Association (Airtime metric): AP2*

⇒ *Best AP for association: AP2*

Throughput improvement: 54%







Sum up

- Association/handover scheme for WLAN that takes into account the channel conditions both in the uplink and downlink as well as the traffic load of the candidate APs
- Cross-layer association/handover scheme for WLAN that considers in addition to the local cell information, the information about the routing of the packets from the candidate APs to the destinations
- Realistic simulation scenario where we study not only the throughput of the wireless cells in a mesh network but also the end-to-end performance of the network
- Implementation of the proposed schemes and experimentation in an 802.11 wireless testbed

More information…

George Athanasiou, Thanasis Korakis, Ozgur Ercetin and Leandros Tassiulas, **"Dynamic Cross-Layer Association in 802.11-based Mesh Networks"**, in *IEEE INFOCOM 2007*, Anchorage, Alaska, USA, May 2007

George Athanasiou, Thanasis Korakis, Ozgur Ercetin and Leandros Tassiulas, **"A Cross-Layer Framework for Association Control in Wireless Mesh Networks"**, in *IEEE Transactions on Mobile Computing*, vol. 8, no. 1, pp. 65-80, Jan., 2009

Thank you!

More information...

http://www.inf.uth.gr/~gathanas