

Mesh Deterministic Access (MDA) Optional IEEE 802.11s MAC scheme Simulation results

Date: 2006-09-08

Notice: This document has been prepared to assist IEEE 802.11. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein.

Release: The contributor grants a free, irrevocable license to the IEEE to incorporate material contained in this contribution, and any modifications thereof, in the creation of an IEEE Standards publication; to copyright in the IEEE's name any IEEE Standards publication even though it may include portions of this contribution; and at the IEEE's sole discretion to permit others to reproduce in whole or in part the resulting IEEE Standards publication. The contributor also acknowledges and accepts that this contribution may be made public by IEEE 802.11.

Patent Policy and Procedures: The contributor is familiar with the IEEE 802 Patent Policy and Procedures <<http://ieee802.org/guides/bylaws/sb-bylaws.pdf>>, including the statement "IEEE standards may include the known use of patent(s), including patent applications, provided the IEEE receives assurance from the patent holder or applicant with respect to patents essential for compliance with both mandatory and optional portions of the standard." Early disclosure to the Working Group of patent information that might be relevant to the standard is essential to reduce the possibility for delays in the development process and increase the likelihood that the draft publication will be approved for publication. Please notify the Chair <stuart.kerry@philips.com> as early as possible, in written or electronic form, if patented technology (or technology under patent application) might be incorporated into a draft standard being developed within the IEEE 802.11 Working Group. **If you have questions, contact the IEEE Patent Committee Administrator at <patcom@ieee.org>.**

Authors:

Name	Company	Address	Phone	email
Guido R. Hiertz	Philips	ComNets, RWTH Aachen University Kopernikusstr. 16, 52074 Aachen, Federal Republic of Germany	+49-241-802-5829	hiertz@ieee.org
Thomas Junge	ComNets, Chair of Communication Networks, RWTH Aachen University	Kopernikusstr. 16, 52074 Aachen, Federal Republic of Germany	+49-241-802-5829	thj@comnets.rwth-aachen.de
Sebastian Max	Philips	ComNets, RWTH Aachen University Kopernikusstr. 16, 52074 Aachen, Federal Republic of Germany	+49-241-802-0547	smx@comnets.rwth-aachen.de
Yunpeng Zang	Philips	ComNets, RWTH Aachen University Kopernikusstr. 16, 52074 Aachen, Federal Republic of Germany	+49-241-802-5829	zangyp@ieee.org
Lothar Stibor	Philips	ComNets, RWTH Aachen University Kopernikusstr. 16, 52074 Aachen, Federal Republic of Germany	+49-241-802-3923	lsrc@comnets.rwth-aachen.de
Dee Denteneer	Philips	Philips Research, HTC 27 (WL 1.132), 5656 AE Eindhoven, The Netherlands	+31-402-746-937	dee.denteneer@philips.com

**This version has been edited for publication
as PDF file at ComNets, RWTH Aachen
University.**

**Some animations may not be displayed
correctly in PDF format.**

**Please see <http://802wirelessworld.com> for
the original version in PowerPoint
format.**

Abstract

Mesh Deterministic Access (MDA) is a new Coordination Function (CF) introduced by [4]. To provide simulation results on the efficiency of MDA we use the same simulation tool as in [1]. Our simulation results indicate that MDA operates efficiently in Mesh topologies and avoids congestion without additional means. However, MDA is vulnerably by legacy entities that are not MDA-aware. Traffic segregation is important therefore. Additional means may help to support coexistence of MDA with legacy entities when a single channel needs to be shared.

Simulation set-up

Simulation tool	WARP2 Event-driven simulator, based on SDL, implements original 802.11 code [5]
Channel model	See [1, 2]
Set-ups	See [1, 3]
MDA implementation	According to [4]
MDA parameters	According to [4]
IEEE PHY	802.11a, 5GHz, OFDM
TX power	20dBm

Pages 6-10 taken from [1]

Simulation Environment – Propagation model

- **Path loss model**

- P_{Tx} : transmission power
- d : distance between transmitter and receiver
- γ : damping factor, depending on scenario, incorporating antenna gains, reflection, scattering
 - $\gamma = 2$: Free space attenuation
 - $\gamma > 2$: More realistic path loss, LOS/NLOS, indoor/outdoor environments
 - **Here: $\gamma = 3.5$**
- f_c : center frequency
 - **Here: $f_c = 5\text{GHz}$**
- Antenna gains can be included (Rx & Tx)

$$P_{Rx} = \frac{P_{Tx}}{d^\gamma} \cdot \left(\frac{c}{f_c \cdot 4\pi} \right)^2$$

Simulation Environment – Channel model

- **Additional obstacles (e.g. walls, doors)**
 - Attenuation is subtracted from P_{Rx} (in dB)
- **Signal to Interference plus Noise Ratio (SINR)**
 - Signal (S) = $P_{Rx, wanted}$
 - Interference (I) = $P_{Rx, unwanted, i}$
 - i interferer, $i \geq 0$
 - Noise (N)
 - Thermal environment noise, **Here: N = -95 dBm**

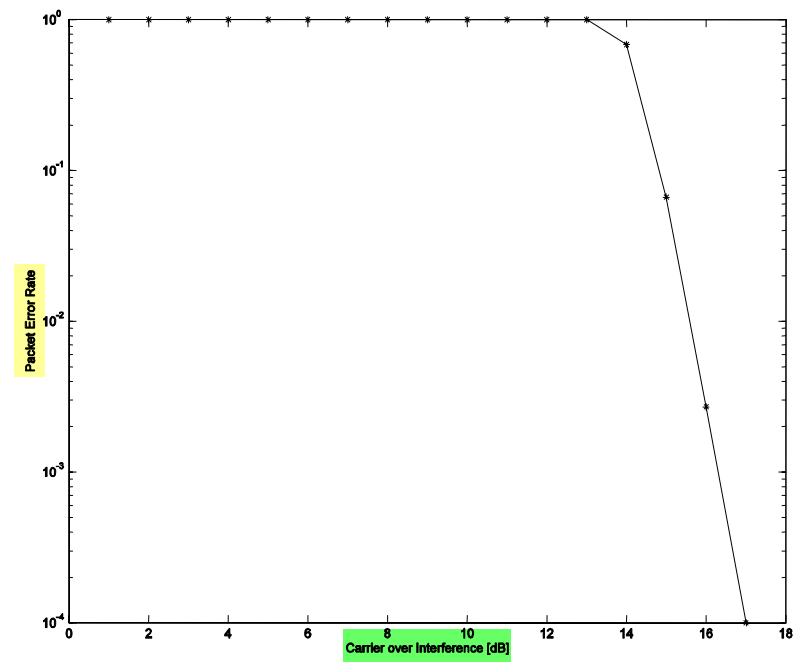
$$SINR = \frac{P_{Rx, wanted}}{N + \sum_i P_{Rx, unwanted, i}}$$

Simulation Environment – PHY layer model

- **Modeling packet error probability**

$$p(\text{error}) = f(P_{\text{Rx, wanted}}, \text{SINR}, \text{Packetlength}, \text{MCS})$$

- Minimal $P_{\text{Rx, wanted}}$
 - Sensitivity (see .11a standard)
 - Depending on Modulation and Coding Scheme (MCS)
- Link level mapping (Packet Error Rate vs. SINR)
 - Tables derived from real hardware measurements
 - Parameterized by
 - MCS
 - Packet length
 - Complementary PER, see example figure



Simulation Environment – PHY layer

- **IEEE 802.11a**
 - Clear Channel Assessment
 - 5GHz, OFDM PHY
 - Busy detection for
 - Any Rx signal > -62 dBm
 - Valid OFDM preamble, Rx level > -82 dBm

Simulation scenario set-up

- **Single radio, single frequency channel Mesh WLAN**
 - 20dBm transmission power
- **Offered traffic: Constant Bit Rate (CBR)**
- **EDCA parameters**
 - TxOP duration = 2048 μ s
 - Backoff settings,
see 802.11e values for
802.11a OFDM PHY

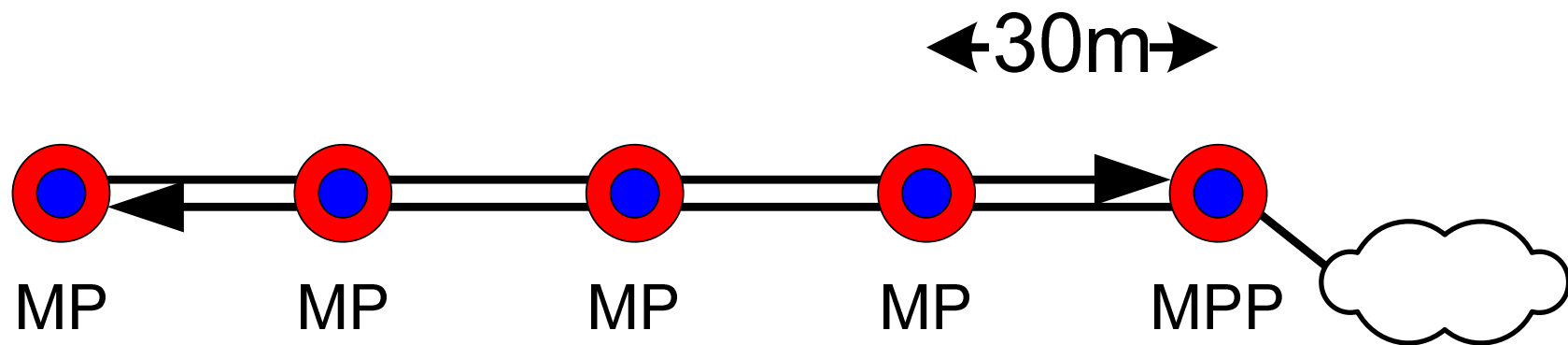
Priority	CWmin	CWmax	AIFS/ μ s
0 (Best Effort)	15	1023	43
7 (Voice)	3	7	34

Simulation results

Basic scenario – Straight multi-hop route

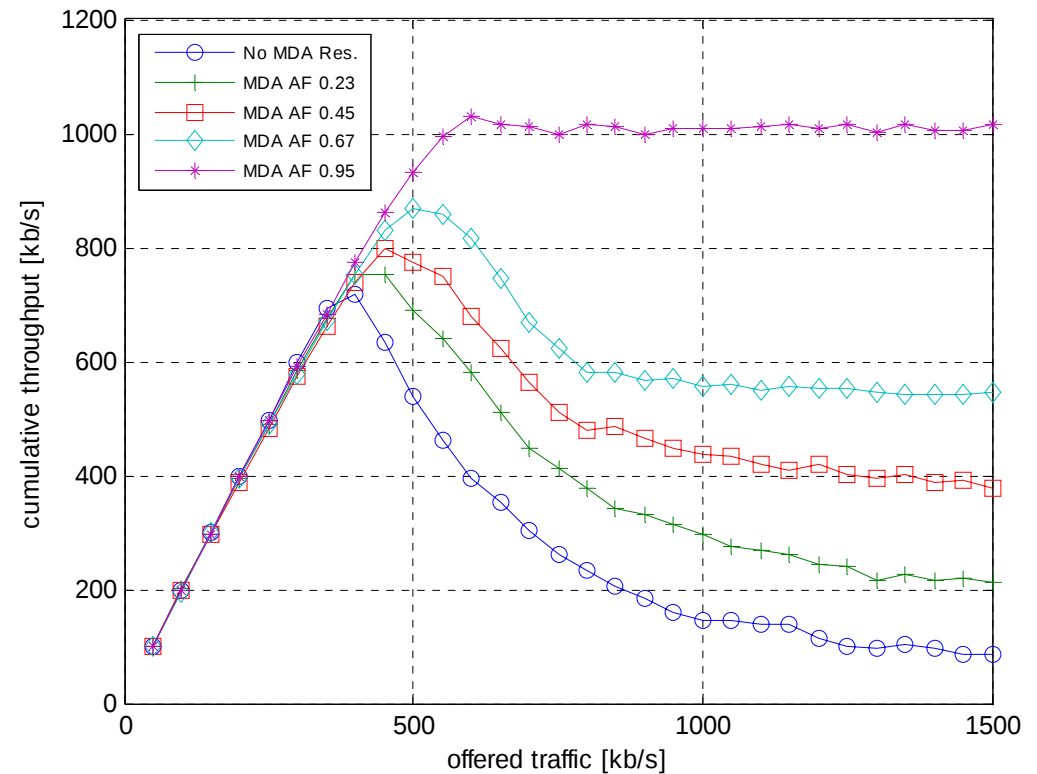
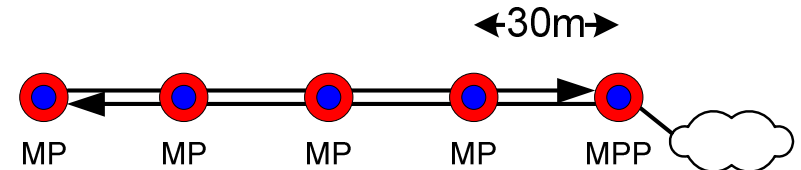
- **4 hop route**

- Duplex data transmission
- Up- & Downlink traffic
- All MPs MDA capable
- MCS: QPSK $\frac{1}{2}$ (12Mb/s)
- 80 B packet size
- MP is sink & source of traffic
- MPP as gateway to Internet



4 hop route – Simulation results

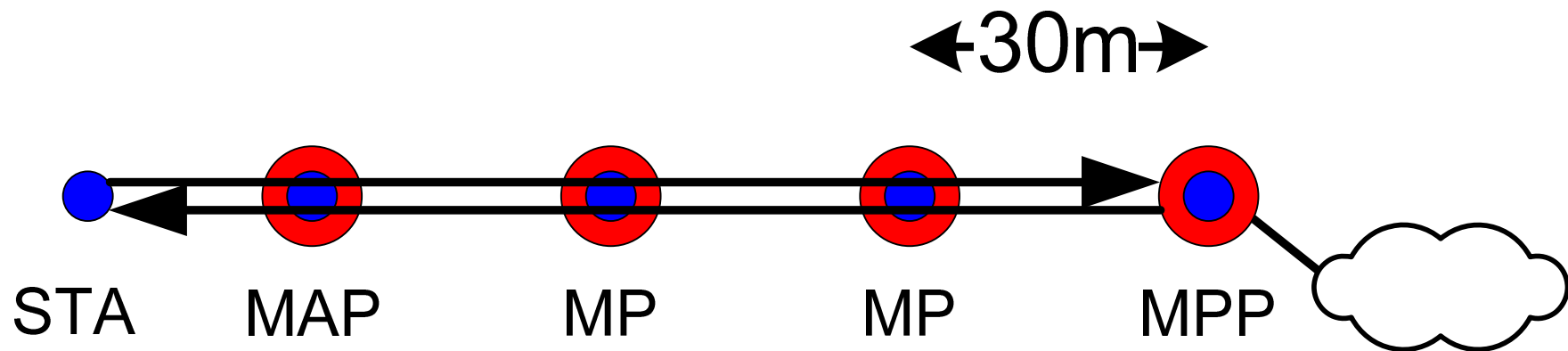
- **MDA more efficient than EDCA**
 - Lack of Congestion Control limits performance with low MDAF
 - For EDCA only compare to [1]
- **Low MDAF values limit efficiency**



Basic scenario – Straight multi-hop route

- **4 hop route**

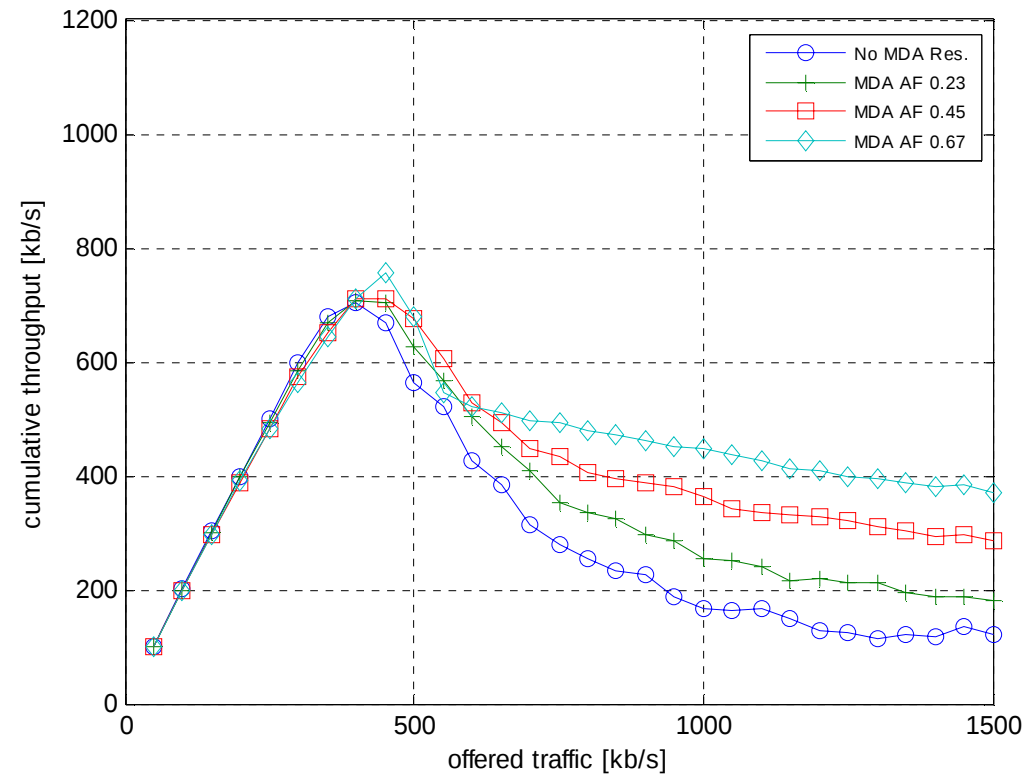
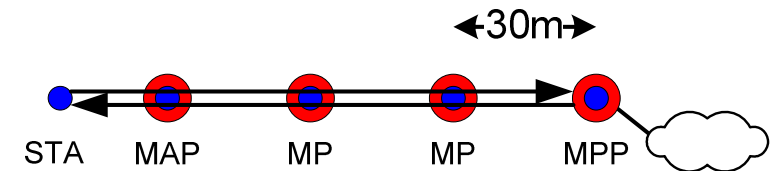
- Duplex data transmission
- Up- & Downlink traffic
- All MPs MDA capable
- MCS: QPSK $\frac{1}{2}$ (12Mb/s)
- 80 B packet size
- STA attached to MAP
- STA is sink & source of traffic
- MPP as gateway to Internet



4 hop route – Simulation results

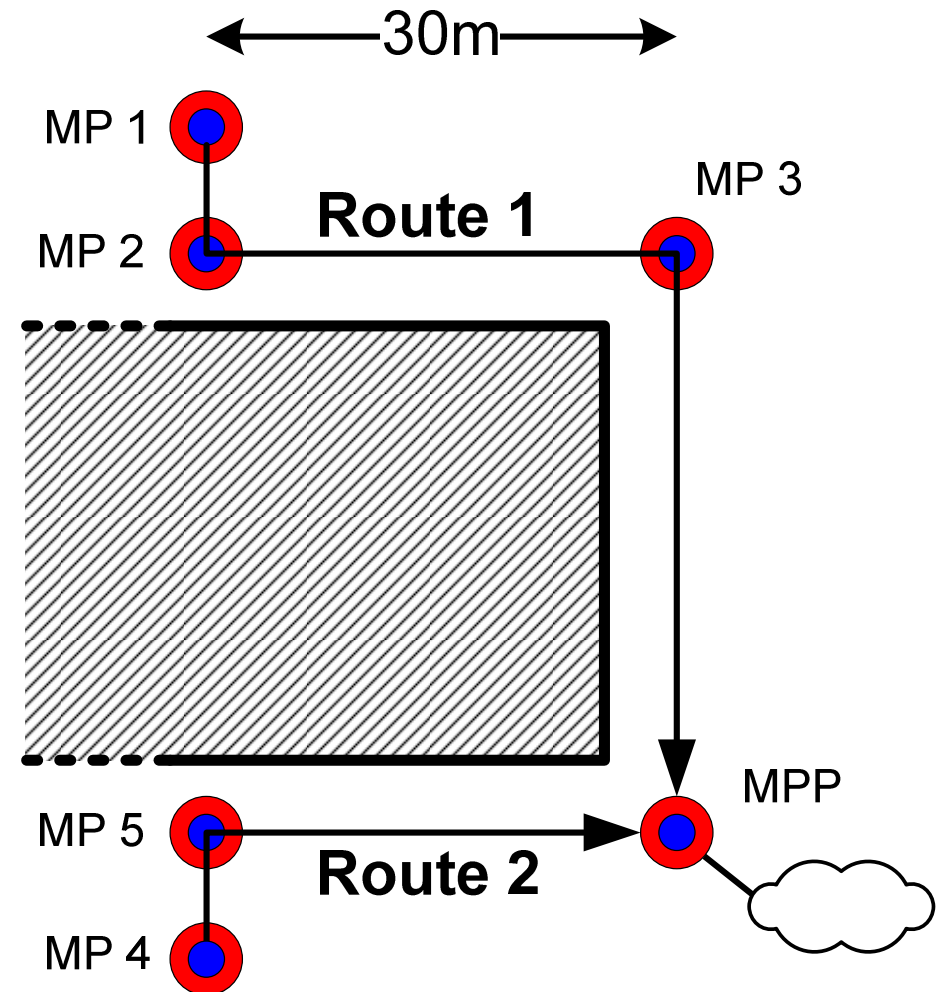
- **MDA unaware station**

- Interference for MDA MPs
- No congestion control at station
- Limits system performance
- No traffic segregation possible



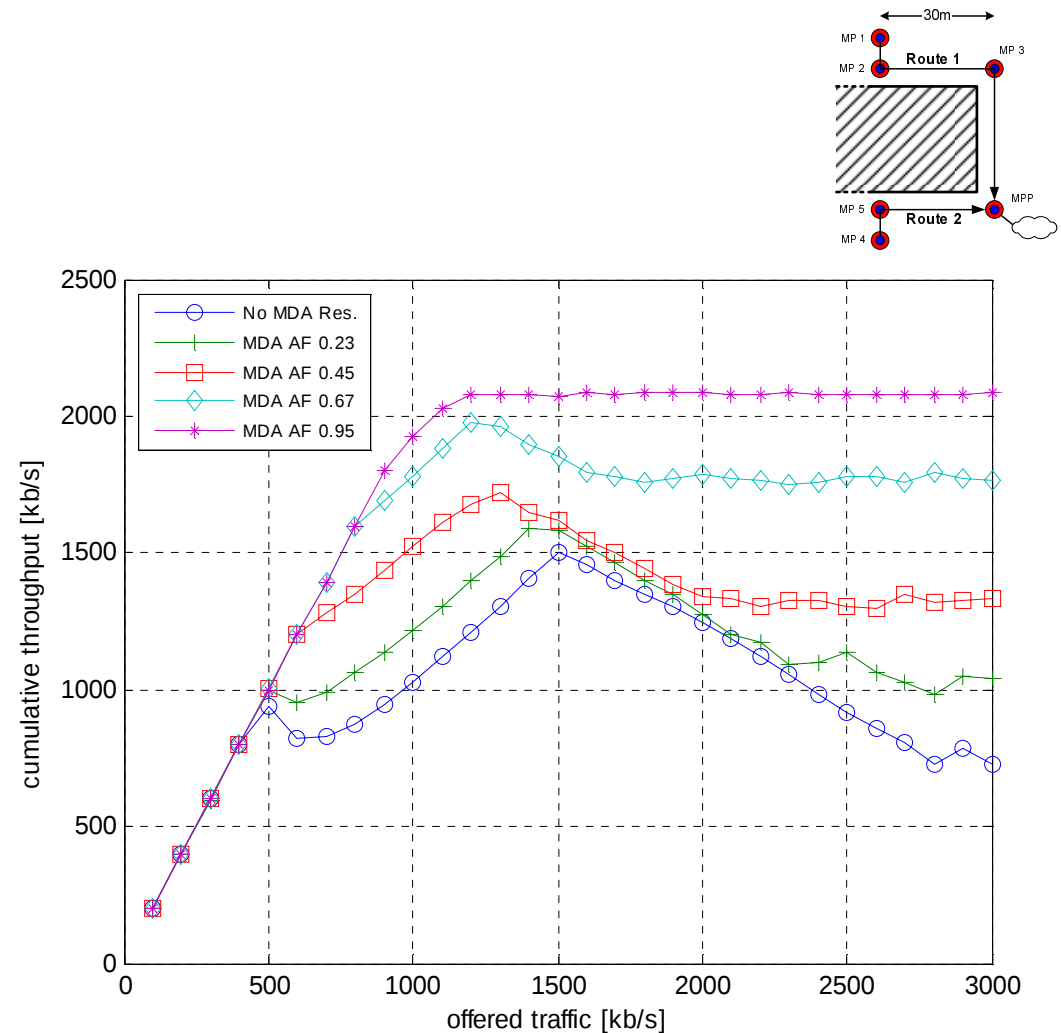
Public access scenario

- **Building attenuates signal: 100 dB**
- **Uplink traffic sent from MPs to Internet**
 - 3 hop route
 - MP 1 → MP 2 → MP 3 → MPP
 - 2 hop route
 - MP 4 → MP 5 → MPP
 - MCS: QPSK^{1/2} (12Mb/s)
 - 80 B packet size



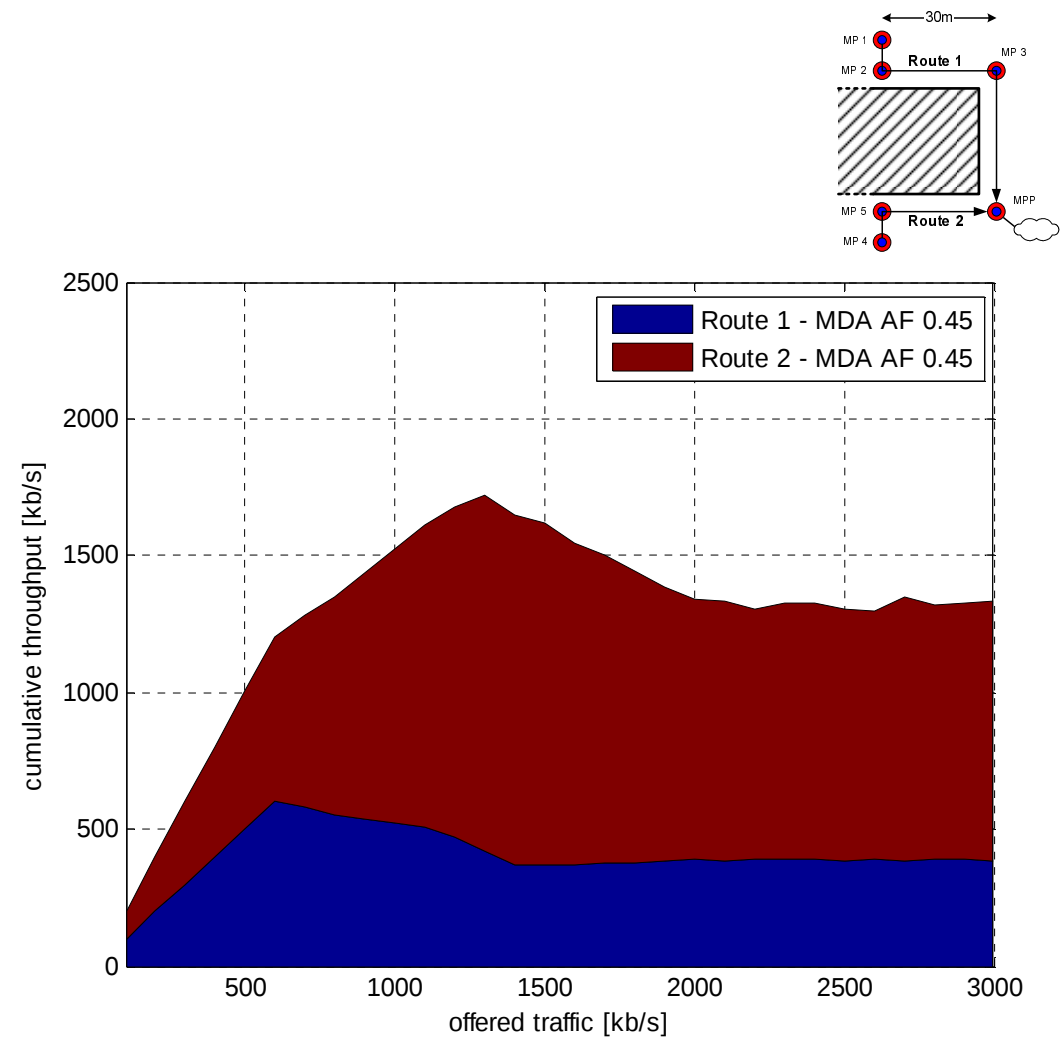
Public access scenario – Simulation results

- **High MDAF provides efficient medium usage**
- **Low MDAF limited by EDCA**
 - EDCA efficiency decreases without congestion control
 - MDA performance = 1.4 EDCA performance



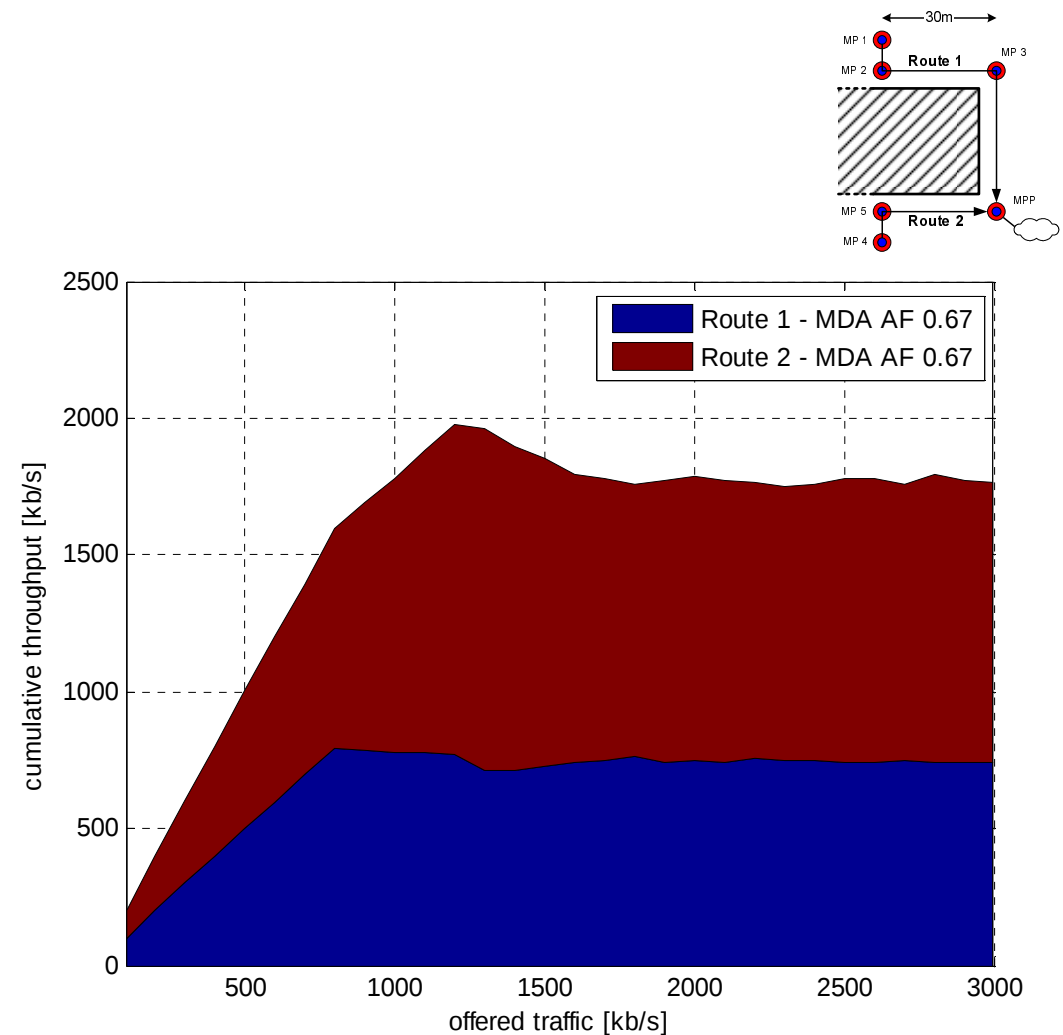
Public access scenario – Simulation results

- **Low MDAF cannot guarantee fairness**
- **Route 2 dominates**
- **MDA limits starvation of Route 1**



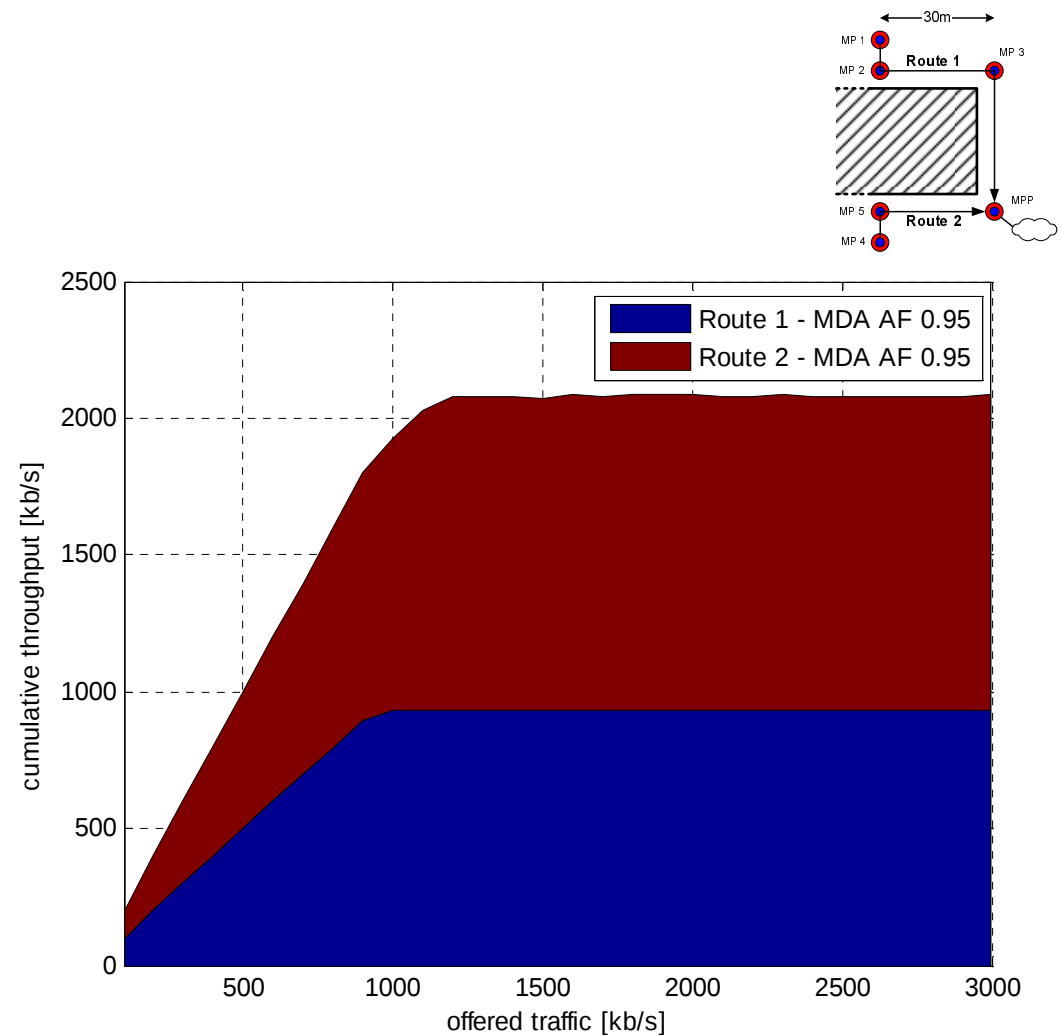
Public access scenario – Simulation results

- Fairness increases with higher MDAF
- Route 2 dominates
- MDAF defines capacity left for Route 1



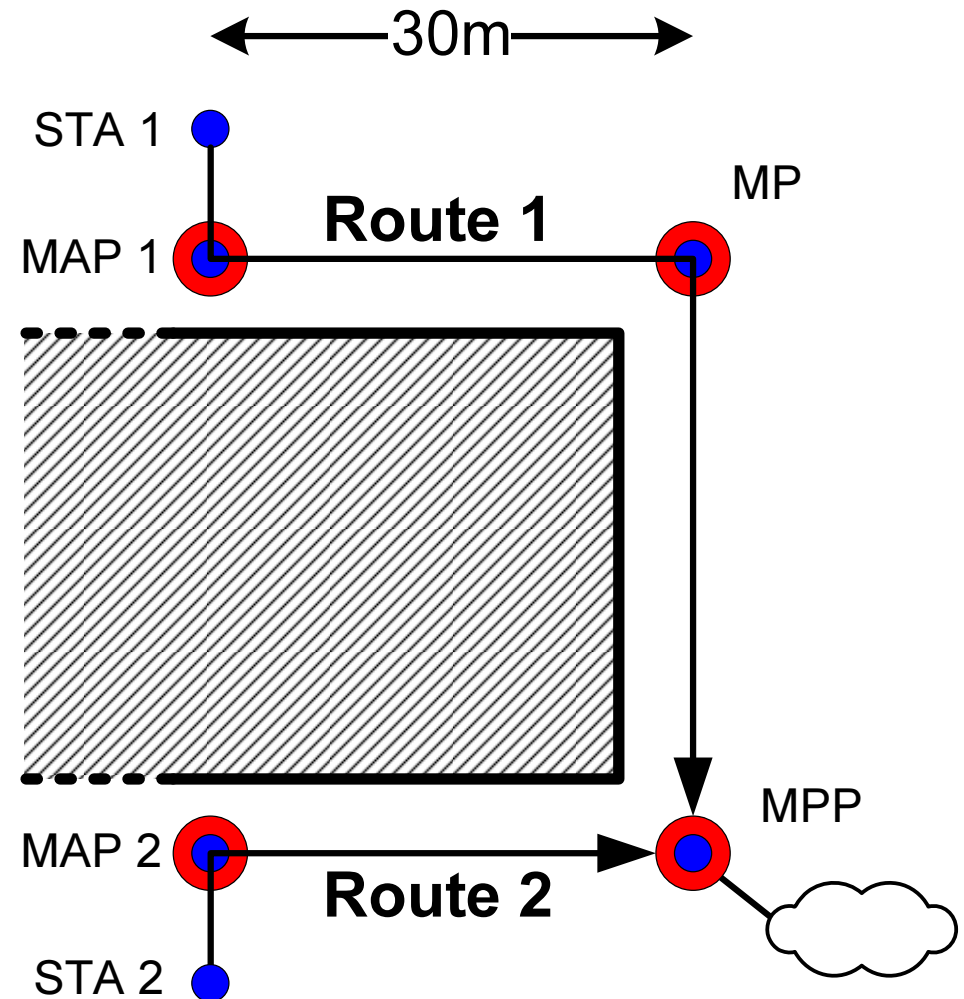
Public access scenario – Simulation results

- **High MDAF achieves fair sharing**
- **Capacity of the wireless medium can be equally used**
- **No differences in hop count**



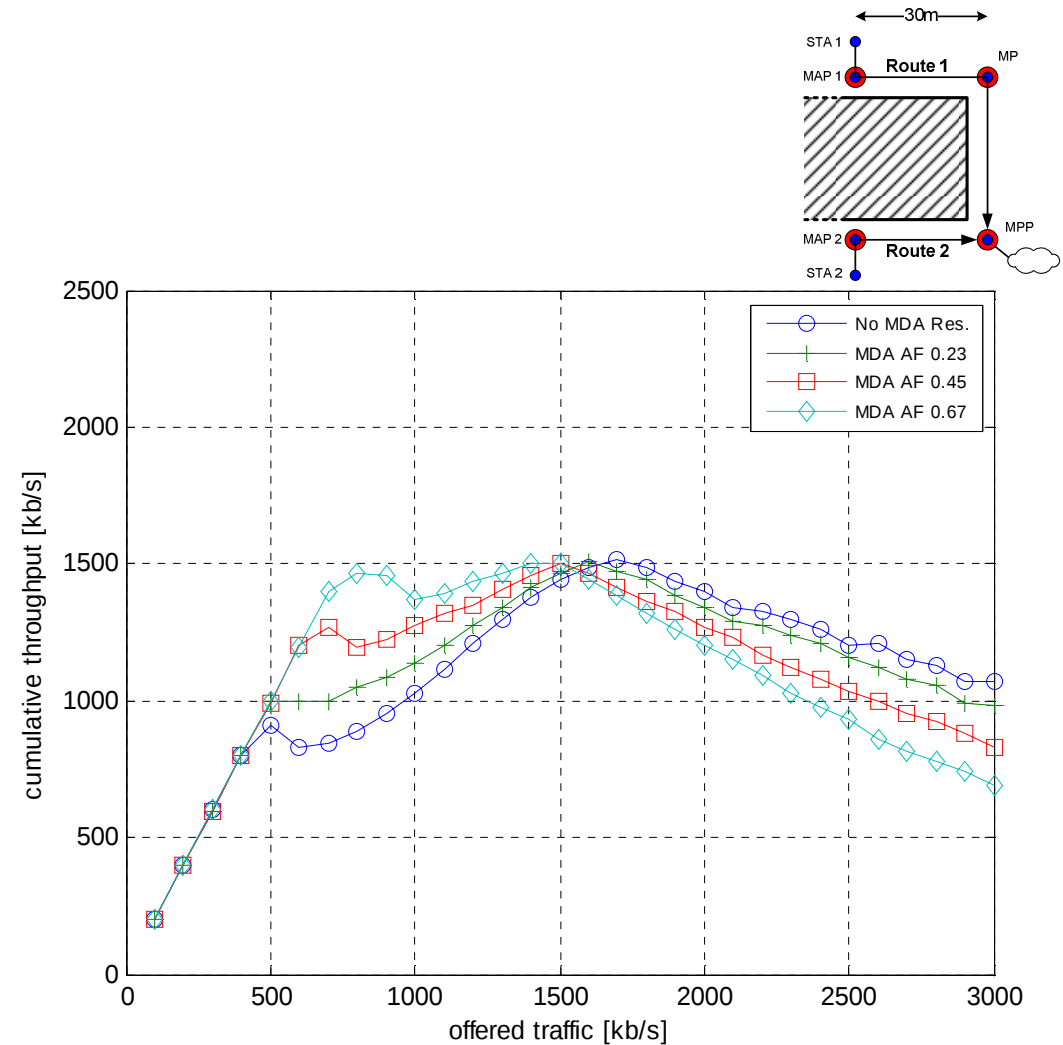
Public access scenario

- **Building attenuates signal: 100 dB**
- **Uplink traffic sent from STAs to Internet**
 - 3 hop route
 - STA 1 → MAP 1 → MP → MPP
 - 2 hop route
 - STA 2 → MAP 2 → MPP
 - MCS: QPSK $\frac{1}{2}$ (12Mb/s)
 - 80 B packet size



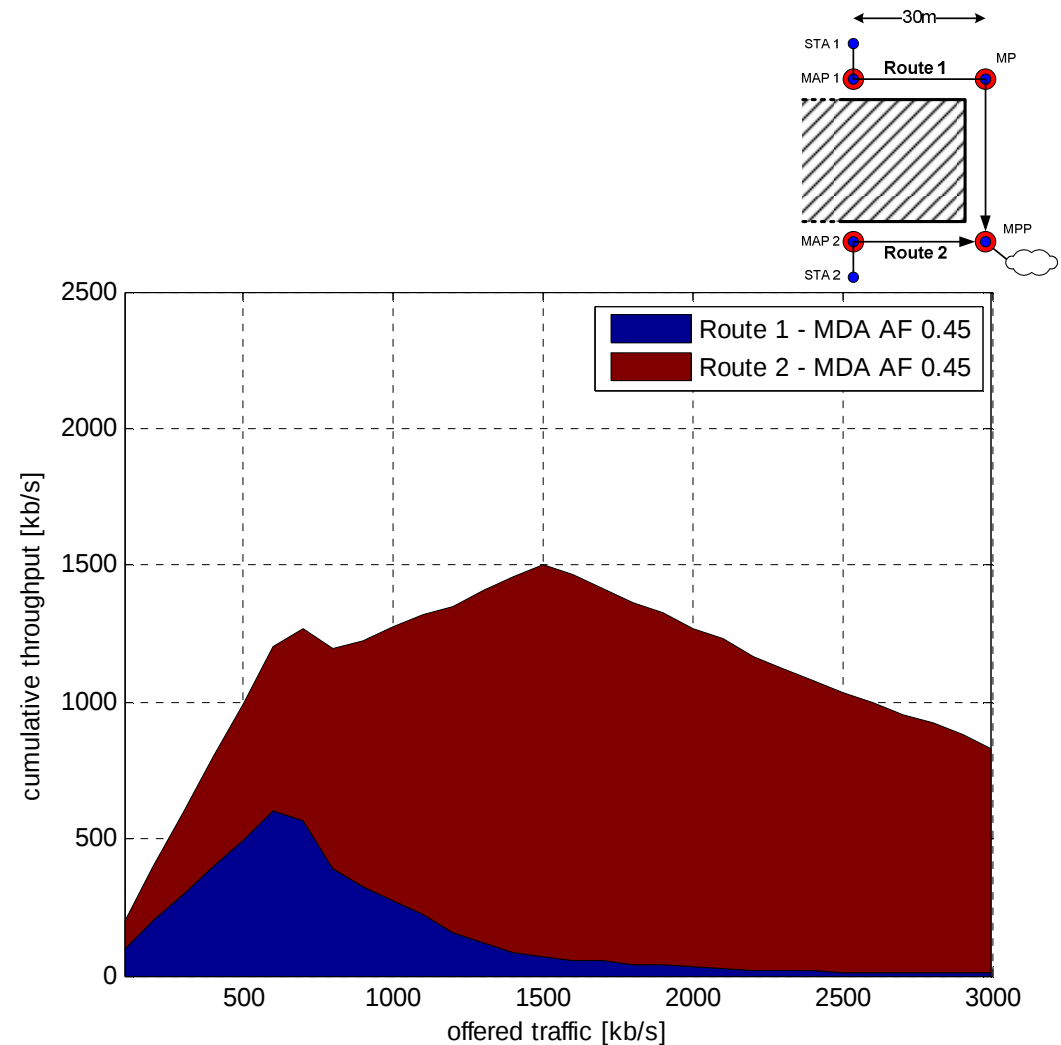
Public access scenario – Simulation results

- Stations limit overall performance
- No congestion control at stations possible
- MDA MPs compete with EDCA stations on capacity



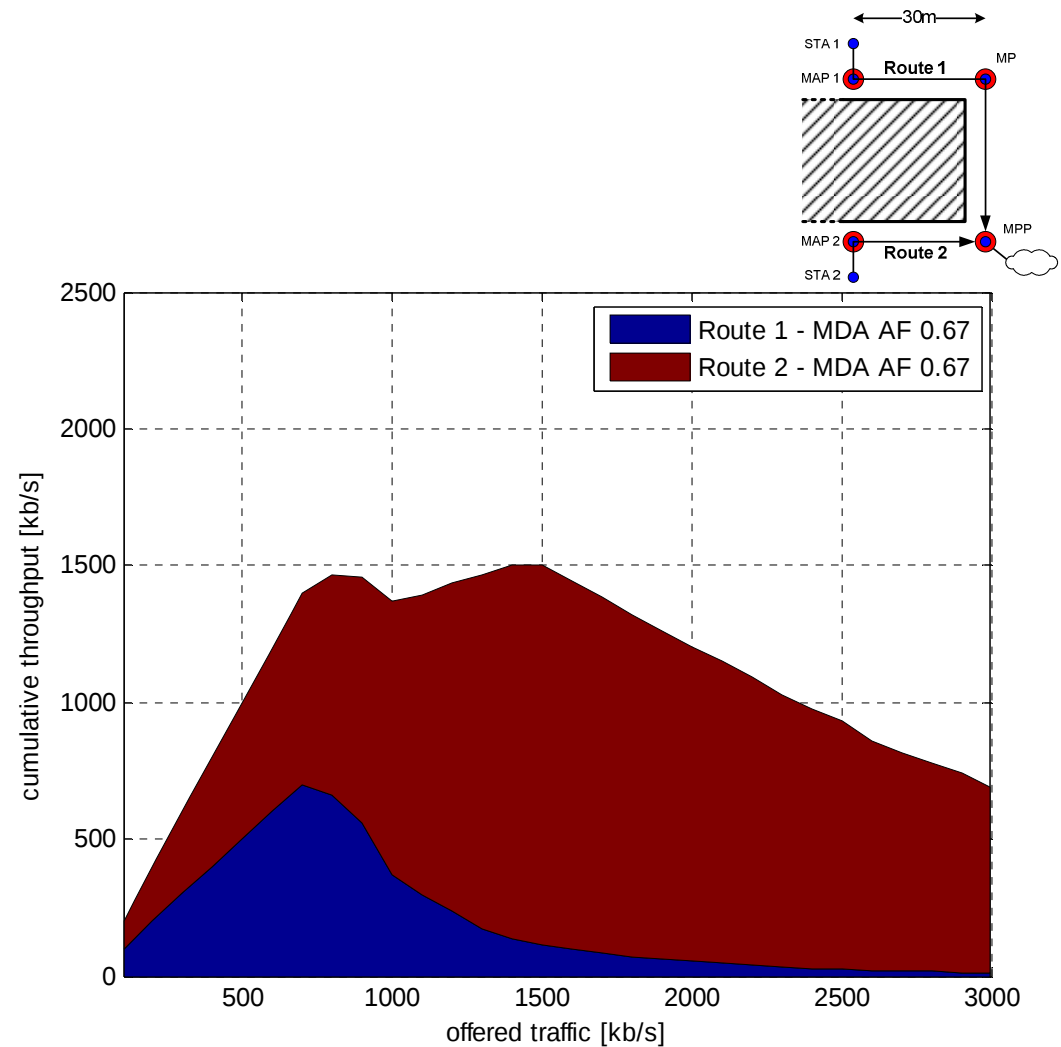
Public access scenario – Simulation results

- APs flooded by their associated stations
- Route 2 totally dominates Route 1
- High amount of offered traffic leads to starvation of Route 1



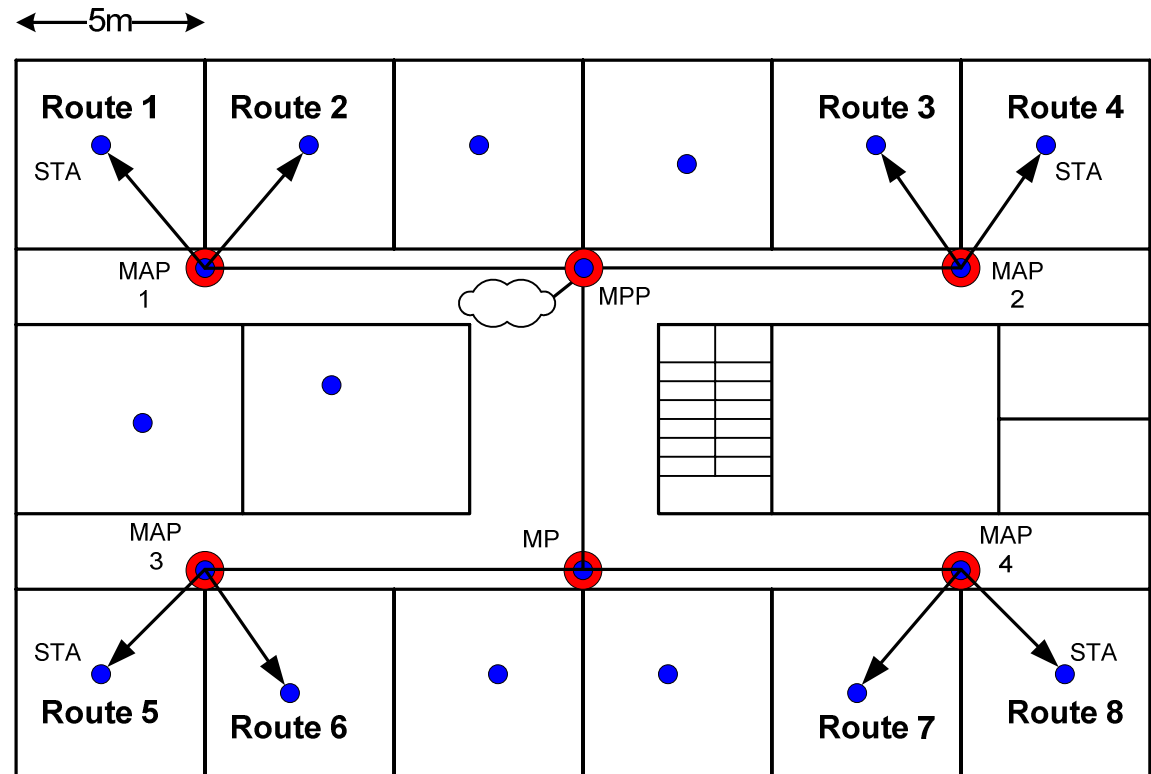
Public access scenario – Simulation results

- Increased MDAF cannot prevent starvation in presence of MDA unaware stations
- Traffic segregation impossible
- Limited performance of Mesh WLAN



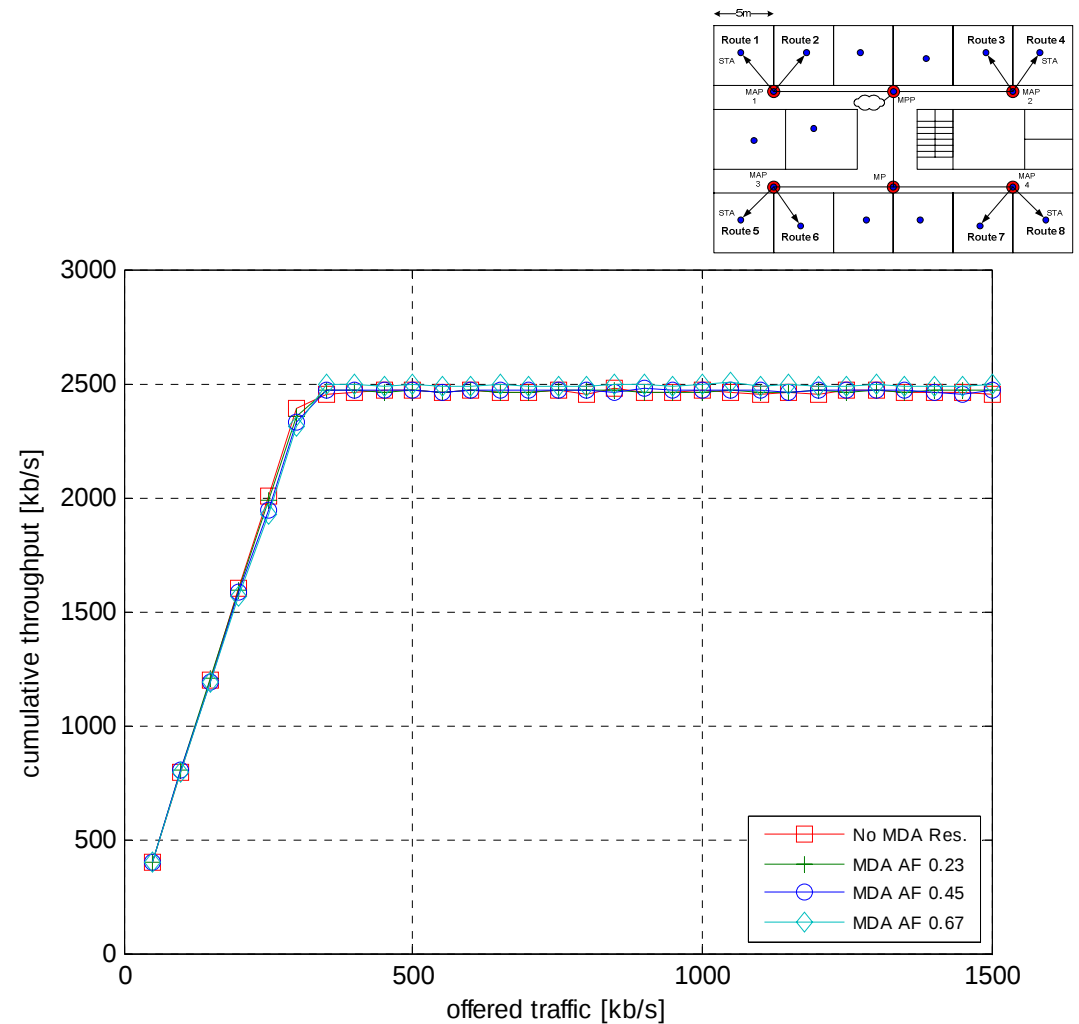
Office scenario

- **Offered traffic:**
CBR
 - Downlink routes
- **MCS: 64QAM^{3/4}**
(54Mb/s)
- **Attenuation**
 - Walls: 13 dB
- **80B packet size**



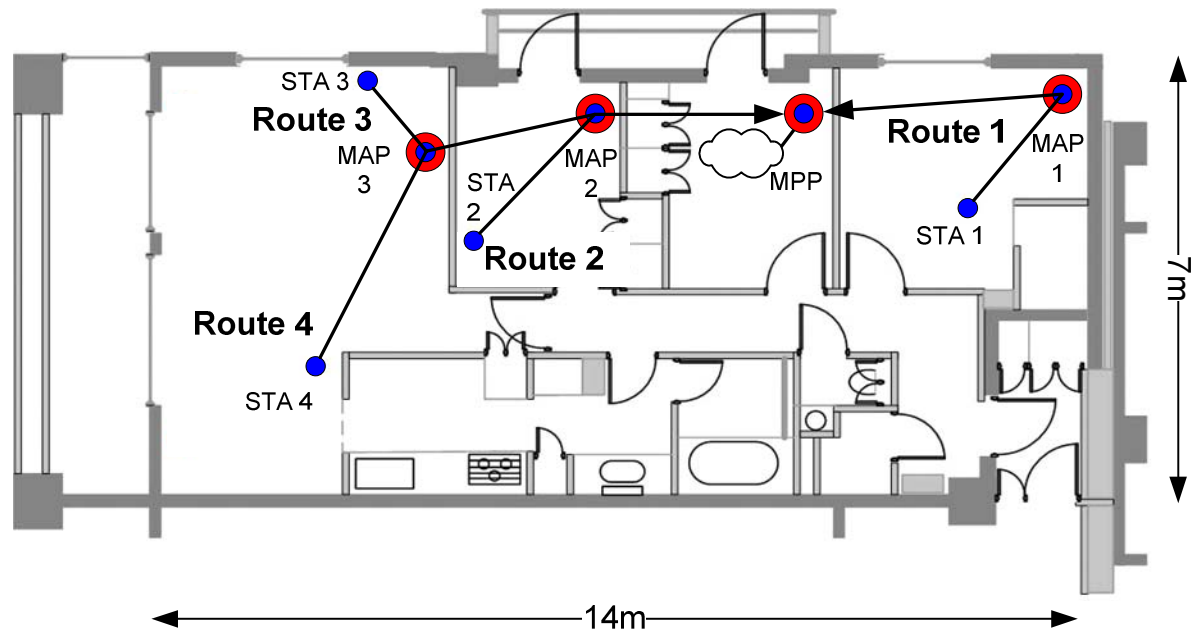
Office scenario – Simulation results

- **Single source of traffic**
 - Downlink only
 - Contention on forwarding hop only
- **Performance limited by lack of spatial frequency reuse**
- **MDA and EDCA perform equal**



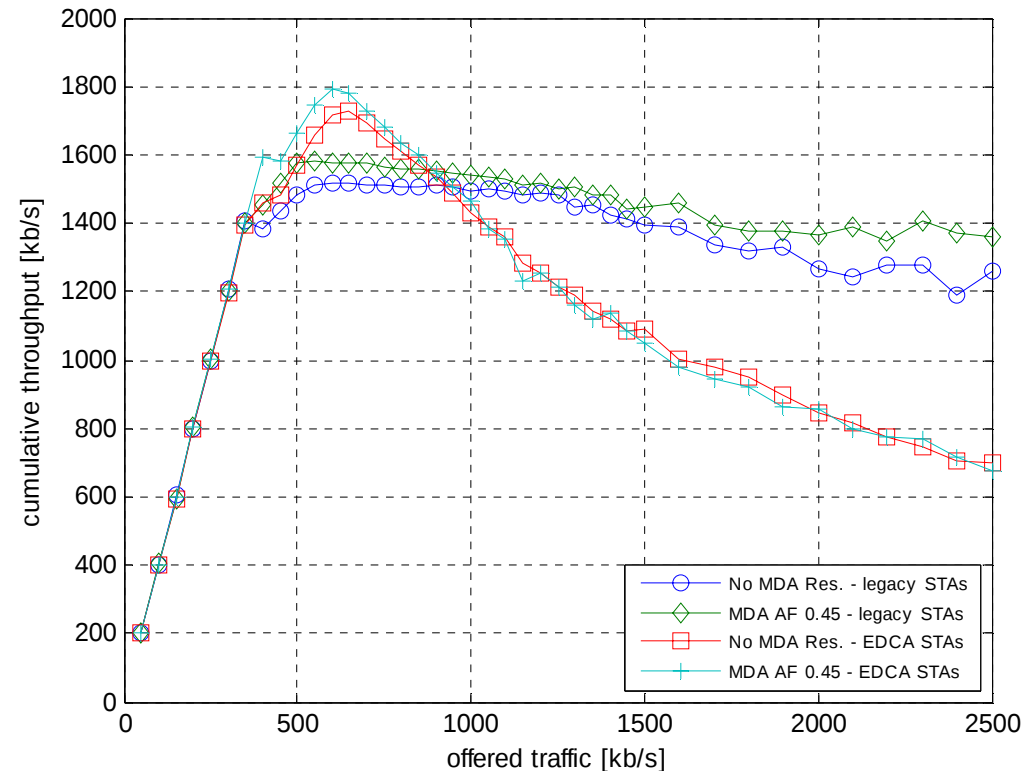
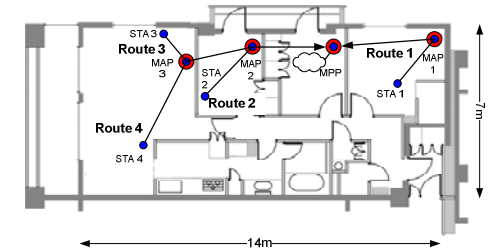
Residential scenario

- **Offered traffic:**
CBR
 - Uplink routes
- **MCS: 64QAM^{3/4}**
(54Mb/s)
- **Attenuation**
 - Walls: 10 dB
 - Doors: 3.5 dB
- **80B packet size**



Residential scenario – Simulation results

- DCF stations send single frame per contention
- EDCA stations send several frames limited by EDCA TXOP duration
 - Long EDCA TXOP limit MDA performance



Conclusion

- **EDCA & DCF operate with low performance**
 - **Congestion Control not sufficient to provide good Mesh WLAN performance**
 - **High performance with MDA possible**
 - **MDA needs protection from EDCA & DCF entities**
- Additional methods to silence stations needed**

References

- [1] 11-05-0600-03-000s-mesh-networks-alliance-proposal.ppt**
- [2] 11-05-0605-02-000s-mesh-networks-alliance-proposal.doc**
- [3] 11-05-0788-02-000s-mna-5min-statement-to-tgs.ppt**
- [4] IEEE P802.11s/D0.03**
- [5] ANSI/IEEE Std. 802.11, 1999 Edition, Annex C (normative), “Formal description of MAC operation”**