Strategies and Guidelines for Improving Wireless Local Area Network Performance

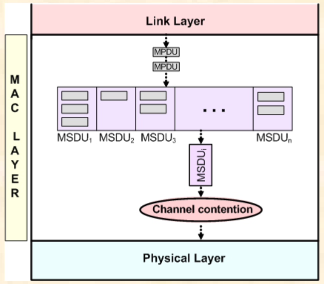
Dr Nurul Sarkar
Associate Professor
School of Computing and Mathematical Sciences
nurul.sarkar@aut.ac.nz

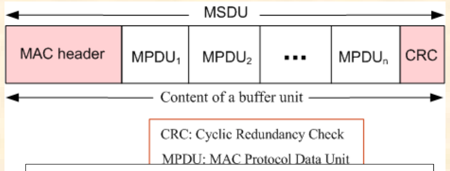
Outline of Talk

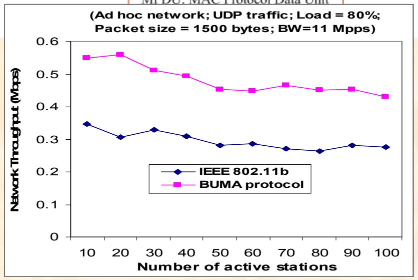
- Factors Influencing WLAN Performance
- Methods of Improving WLAN
- WLAN Deployment Guidelines
- Conclusions

My Research @AUT University

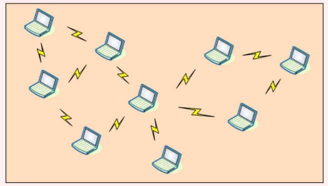
Network Protocols

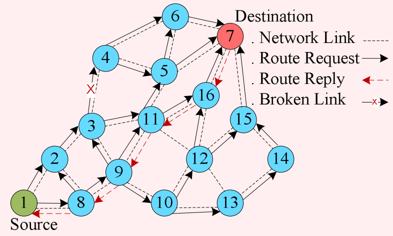


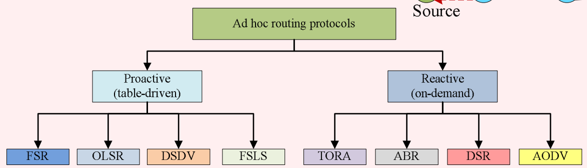




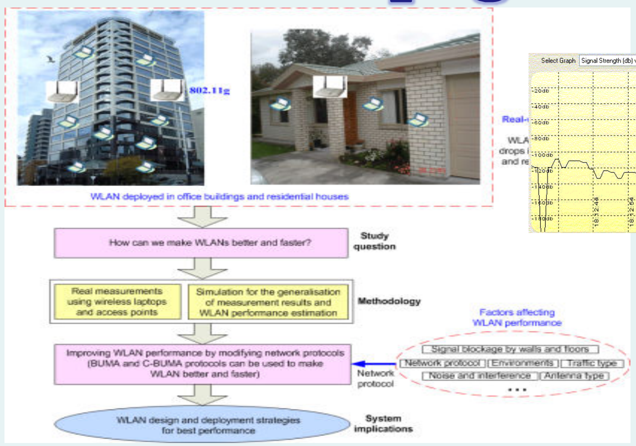
Routing and Transport Protocols

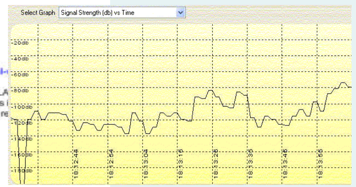




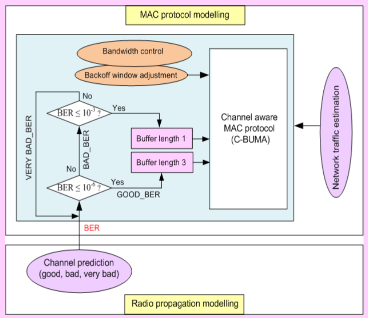


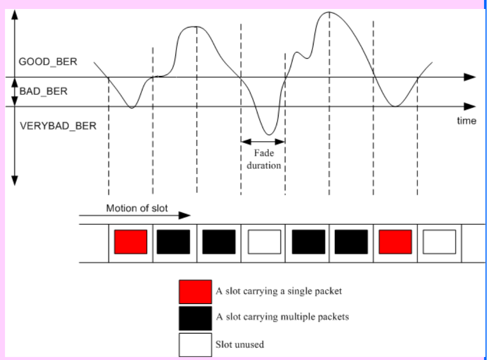
Radio Propagation



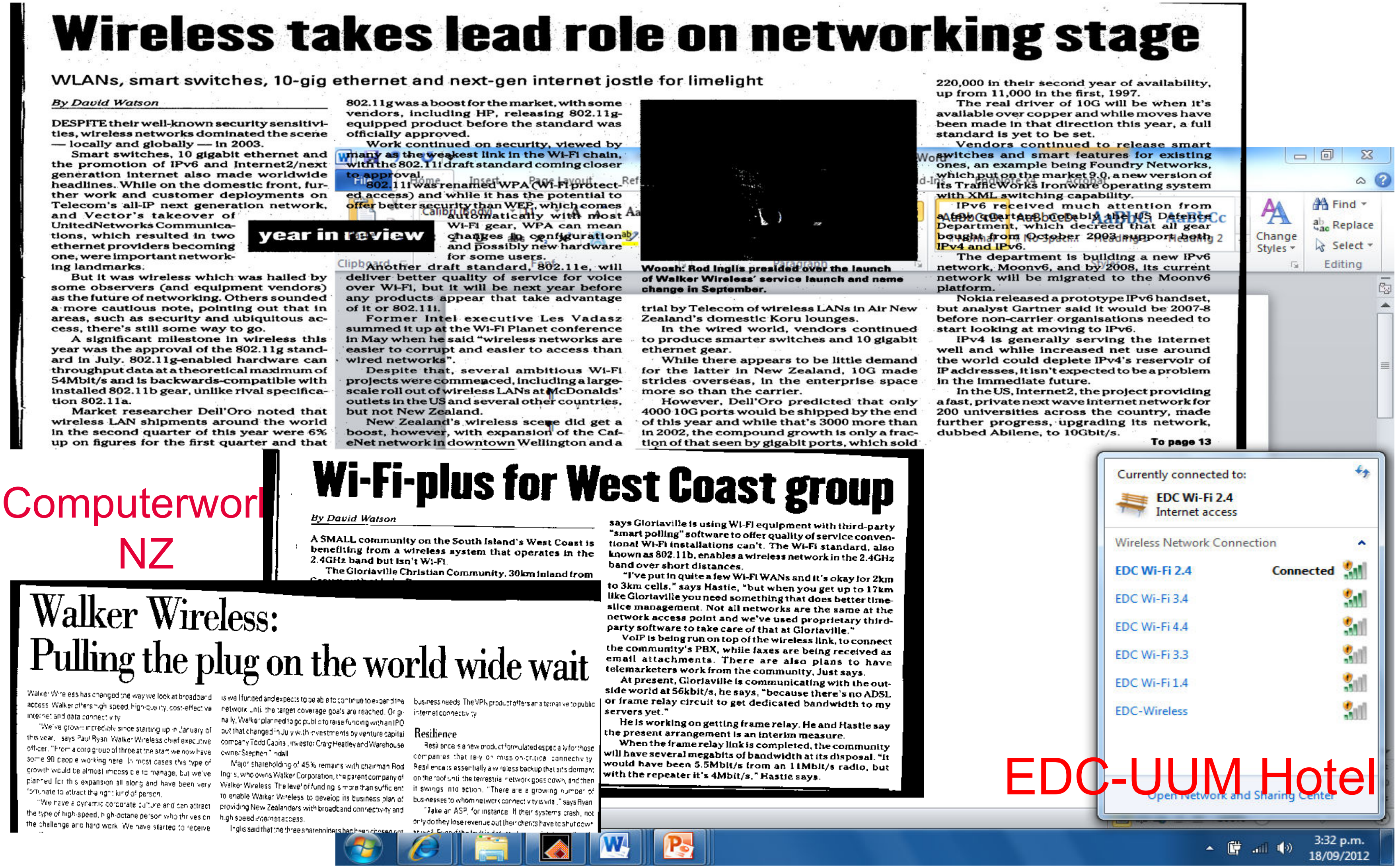


Cross-layer Optimization





Wi-Fi Networks!



Wireless takes lead role on networking stage

WLANs, smart switches, 10-gig ethernet and next-gen internet jostle for limelight

By David Watson

DESPITE their well-known security sensitivities, wireless networks dominated the scene — locally and globally — in 2003.

Smart switches, 10 gigabit ethernet and the promotion of IPv6 and Internet2/next generation internet also made worldwide headlines. While on the domestic front, further work and customer deployments on Telecom's all-IP next generation network, and Vector's takeover of UnitedNetworks Communications, which resulted in two ethernet providers becoming one, were important networking landmarks.

year in review

But it was wireless which was hailed by some observers (and equipment vendors) as the future of networking. Others sounded a more cautious note, pointing out that in areas, such as security and ubiquitous access, there's still some way to go.

A significant milestone in wireless this year was the approval of the 802.11g standard in July. 802.11g-enabled hardware can throughput data at a theoretical maximum of 54Mbit/s and is backwards-compatible with installed 802.11b gear, unlike rival specification 802.11a.

Market researcher Dell'Oro noted that wireless LAN shipments around the world in the second quarter of this year were 6% up on figures for the first quarter and that 802.11g was a boost for the market, with some vendors, including HP, releasing 802.11g-equipped product before the standard was officially approved.

Work continued on security, viewed by many as the weakest link in the Wi-Fi chain, with the 802.11i draft standard coming closer to approval.

802.11i was renamed WPA (Wi-Fi protected access) and while it has the potential to offer better security than WEP, which comes automatically with most Wi-Fi gear, WPA can mean changes in configuration and possibly new hardware for some users.

Another draft standard, 802.11e, will deliver better quality of service for voice over Wi-Fi, but it will be next year before any products appear that take advantage of it or 802.11i.

Former Intel executive Les Vadasz summed it up at the Wi-Fi Planet conference in May when he said "wireless networks are easier to corrupt and easier to access than wired networks".

Despite that, several ambitious Wi-Fi projects were commenced, including a large-scale roll out of wireless LANs at McDonalds' outlets in the US and several other countries, but not New Zealand.

New Zealand's wireless scene did get a boost, however, with expansion of the CafeNet network in downtown Wellington and a

Woosh: Rod Inglis presided over the launch of Walker Wireless' service launch and name change in September.

trial by Telecom of wireless LANs in Air New Zealand's domestic Koru lounges.

In the wired world, vendors continued to produce smarter switches and 10 gigabit ethernet gear.

While there appears to be little demand for the latter in New Zealand, 10G made strides overseas, in the enterprise space more so than the carrier.

However, Dell'Oro predicted that only 4000 10G ports would be shipped by the end of this year and while that's 3000 more than in 2002, the compound growth is only a fraction of that seen by gigabit ports, which sold 220,000 in their second year of availability, up from 11,000 in the first, 1997.

The real driver of 10G will be when it's available over copper and while moves have been made in that direction this year, a full standard is yet to be set.

Vendors continued to release smart switches and smart features for existing ones, an example being Foundry Networks, which put on the market 9.0, a new version of its TrafficWorks IronWare operating system with XML switching capability.

IPv6 received much attention from AT&T and the US Department of Defense Department, which decreed that all gear bought from October 2003 support both IPv4 and IPv6.

The department is building a new IPv6 network, Moonv6, and by 2008, its current network will be migrated to the Moonv6 platform.

Nokia released a prototype IPv6 handset, but analyst Gartner said it would be 2007-8 before non-carrier organisations needed to start looking at moving to IPv6.

IPv4 is generally serving the internet well and while increased net use around the world could deplete IPv4's reservoir of IP addresses, it isn't expected to be a problem in the immediate future.

In the US, Internet2, the project providing a fast, private next wave internet network for 200 universities across the country, made further progress, upgrading its network, dubbed Abilene, to 10Gbit/s.

To page 13

Wi-Fi-plus for West Coast group

By David Watson

A SMALL community on the South Island's West Coast is benefiting from a wireless system that operates in the 2.4GHz band but isn't Wi-Fi.

The Gloriaville Christian Community, 30km inland from ...

says Gloriaville is using Wi-Fi equipment with third-party "smart polling" software to offer quality of service conventional Wi-Fi installations can't. The Wi-Fi standard, also known as 802.11b, enables a wireless network in the 2.4GHz band over short distances.

"I've put in quite a few Wi-Fi WANs and it's okay for 2km to 3km cells," says Hastie, "but when you get up to 17km like Gloriaville you need something that does better time-slice management. Not all networks are the same at the network access point and we've used proprietary third-party software to take care of that at Gloriaville."

VoIP is being run on top of the wireless link, to connect the community's PBX, while faxes are being received as email attachments. There are also plans to have telemarketers work from the community, Just says.

At present, Gloriaville is communicating with the outside world at 56kbit/s, he says, "because there's no ADSL or frame relay circuit to get dedicated bandwidth to my servers yet."

He is working on getting frame relay. He and Hastie say the present arrangement is an interim measure.

When the frame relay link is completed, the community will have several megabits of bandwidth at its disposal. "It would have been 5.5Mbit/s from an 11Mbit/s radio, but with the repeater it's 4Mbit/s." Hastie says.

Walker Wireless:
Pulling the plug on the world wide wait

Computerworld NZ

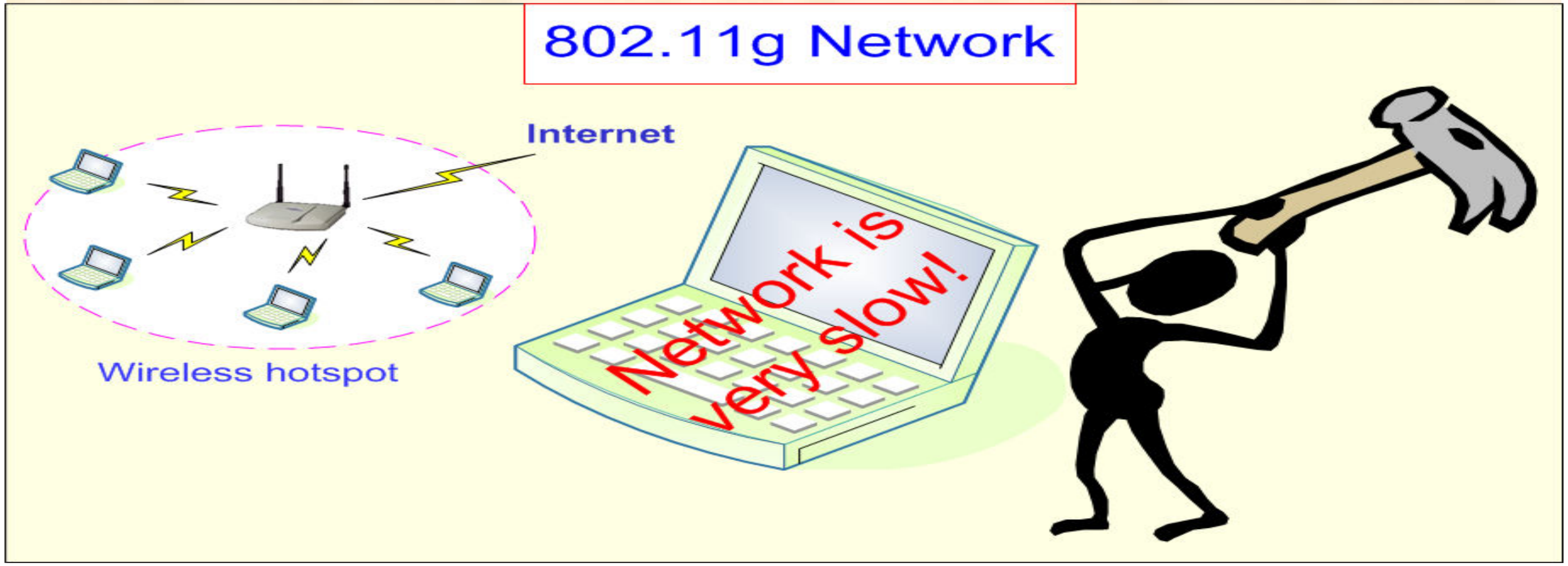
EDC-UUM Hotel

IEEE Standards

- 802.11b/a/g
- 802.11e - QoS
- 802.11s - Wireless mesh for access points
- 802.11n – High data rate (up to 300 Mbps)
- 802.11ac - Very high throughput (1Gbps) – introduced in 2011
- 802.11u – WLAN emergency support (2011)
- 802.11p – Vehicle-to-vehicle comms. (2011)

WLAN Performance Issues

Why are wireless networks slower …?



Data error rates are higher in WLANs.

WLAN has to retransmit corrupted data more often to keep communication going and slows things down.

Research Question

How can we make a WLAN better and faster?

Outline of Talk

- Factors Influencing WLAN Performance
- Methods of Improving WLAN
- WLAN Deployment Guidelines
- Conclusions

Factors Influencing WLAN Performance

Upper layer

Routing protocols   Traffic type   Traffic distribution

MAC protocol and overhead   Contention window size

Packet length

Link layer

Signal strength   Noise and interference   Ceiling

Propagation environment   Wall partition and corner

Concurrent transmission   Type of wall materials

Bit error rate   Multipath   Modulation

Antenna type   … … …

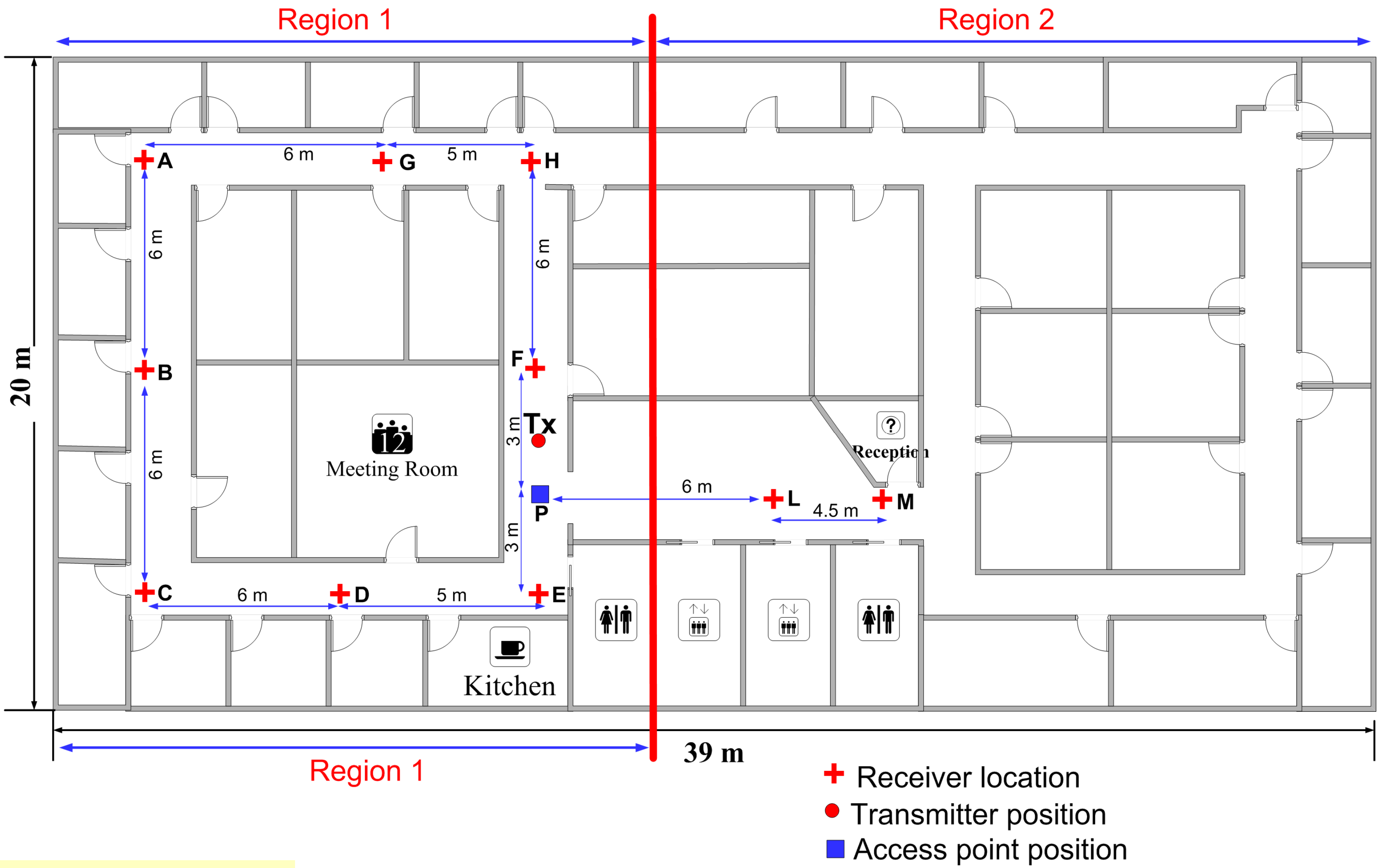
Physical layer

Impact of radio propagation environments on WLAN performance
(Empirical results)

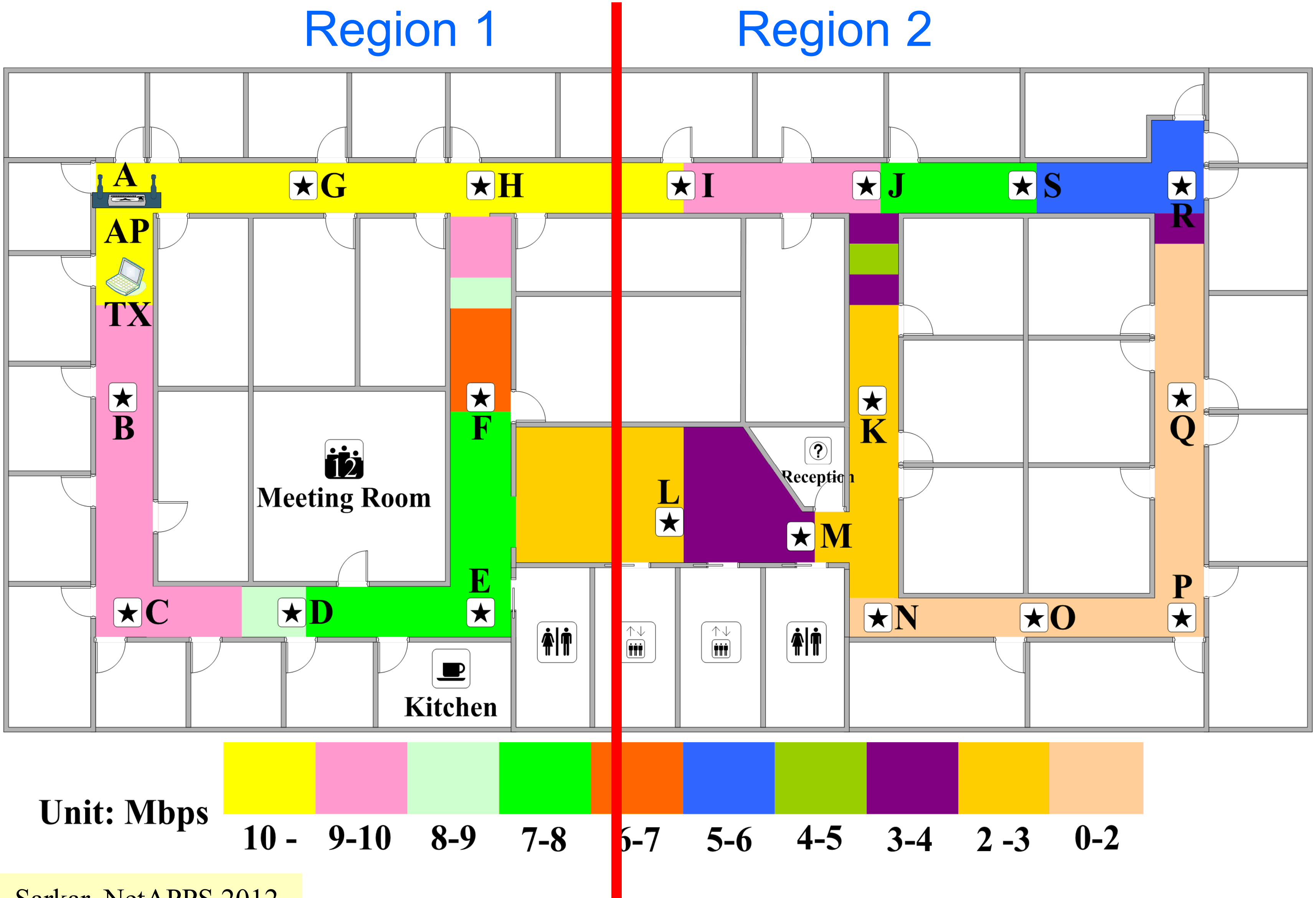
Propagation environments (1)

Office building
(Duthie Whyte)

Floor plan of WY Building



Throughput map (AP at 'A')



Propagation environments (2)

Computer Laboratory (AUT Tower)

Propagation environments (3)

Suburban residential house

Propagation measurements (4)

Measurements

-Two office buildings

- Suburban residential house

Investigation

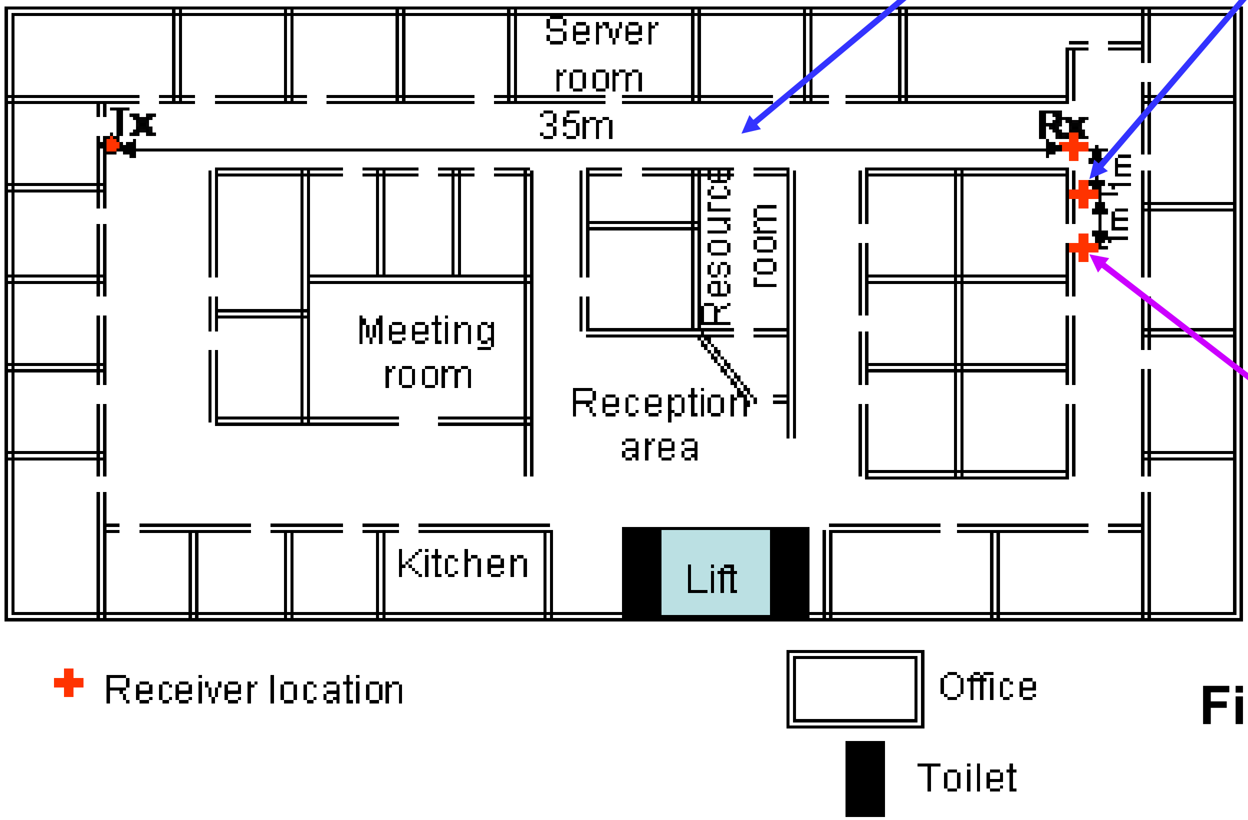
- Transmitting and receiving antennas orientation
- Office wall partitions
- Single wall separation
- Microwave oven interference
- Floors
- Line-of-sight (LOS) blockage by walls

Effect of LOS blockage on WLAN

Obstructed office environment
IEEE 802.11 (11 Mbps)

Throughput: 4.5 Mbps
Distance: 35 m

Throughput:
0.8 Mbps
Distance: 35.01 m



Connection lost
Distance: 35.03 m

File size: 144 MB

Effect of LOS blockage

File size (MB)	Distance between Tx and Rx	Link throughput (Mbps)	Throughput degradation (%)
144	Trial 1: 35m	4.5	0
	Trial 2: 35m+ 1m	0.8	82.2
	Trial 3: 35m +2m	Connection lost	

IEEE 802.11g Throughput

Rx position	AP-Rx separation (m)	RSS (dBm)	Transmission time (seconds)	Throughput (Mbps)	Throughput degradation (%)
A	14.2	-73	12.6	6.92	36.51
B	11.4	-68	9.5	9.18	15.79
C	11.4	-60	8.2	10.63	2.44
D	5.8	-62	9.4	9.28	14.89
E	3.0	-43	8.2	10.63	2.44
F	3.0	-55	8.1	10.77	1.23
G	10.3	-63	8.5	10.26	5.88
H	9.0	-60	8.0	10.90	0.00
L	6.0	-55	8.7	10.02	8.05
M	10.5	-57	9.5	9.18	15.79

Summary of findings

Signal blockage by walls and floors was found to have a significant effect on throughput of 802.11 networks.

Sarkar, N.I. and Lo, E. (2008) "Indoor Propagation Measurements for Performance Evaluation of IEEE 802.11g" – IEEE ATNAC'08.

Sarkar, N.I. and Sowerby, K. (2006) "Wi-Fi Performance Measurements in the Crowded Office Environment: A Case Study"– IEEE ICCT 2006.

Outline of Talk

- ✓ Factors Influencing WLAN Performance
- o Methods of Improving WLAN
- o WLAN Deployment Guidelines
- o Conclusions

Methods of Improving WLAN Performance

Shortcomings of 802.11 WLANs

- Low bandwidth utilization
  - Low throughput and high packet delay
- High transmission overhead

Solution: IEEE 802.11 requires an improvement

Improving 802.11 performance by modifying MAC protocols

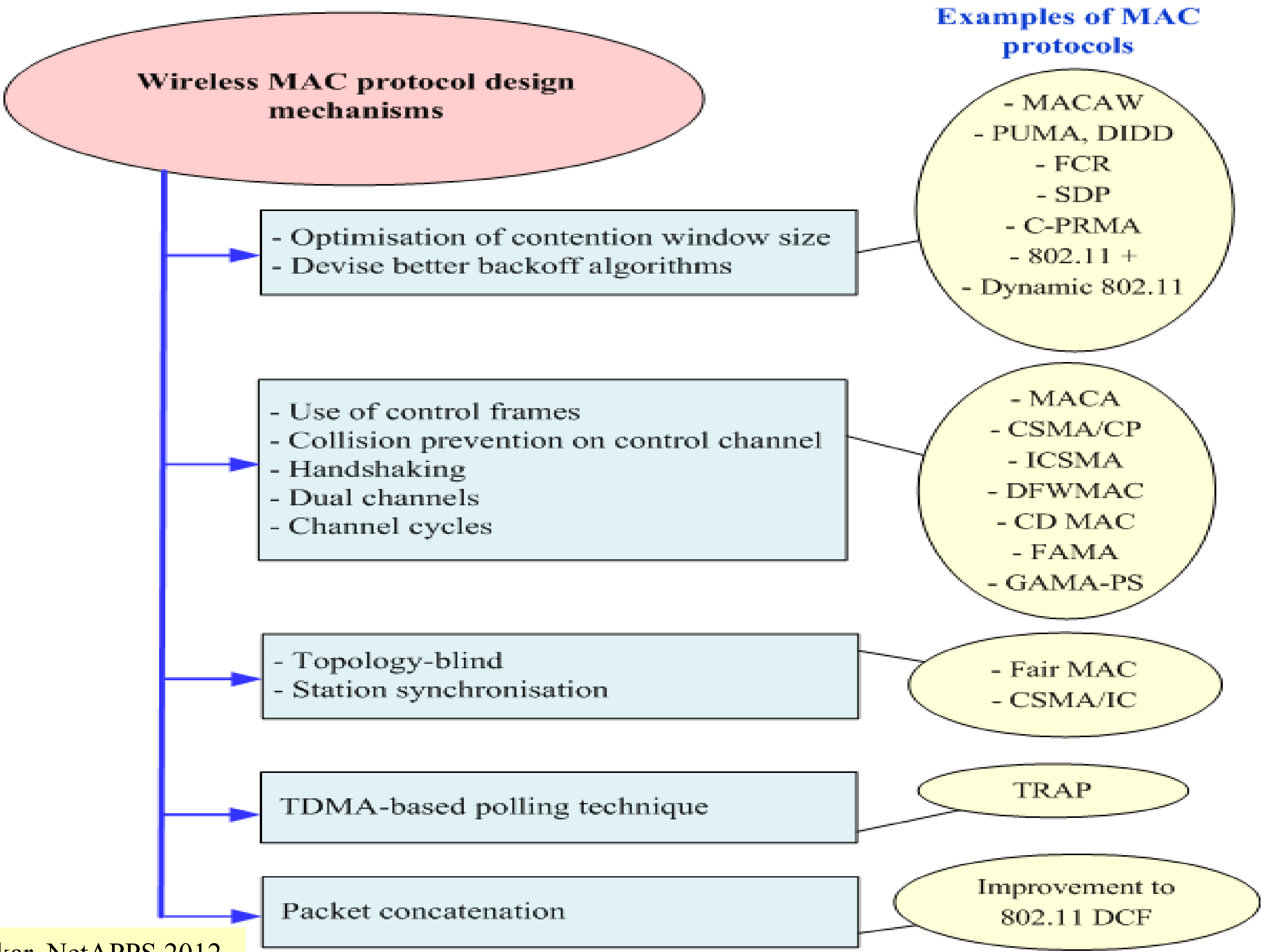
- We have developed a wireless MAC protocol called buffer unit multiple access (BUMA).

- Key idea: Maximize packet transmission
  - » Spend less time in the backoff state
  - » Send a larger payload under good channel state

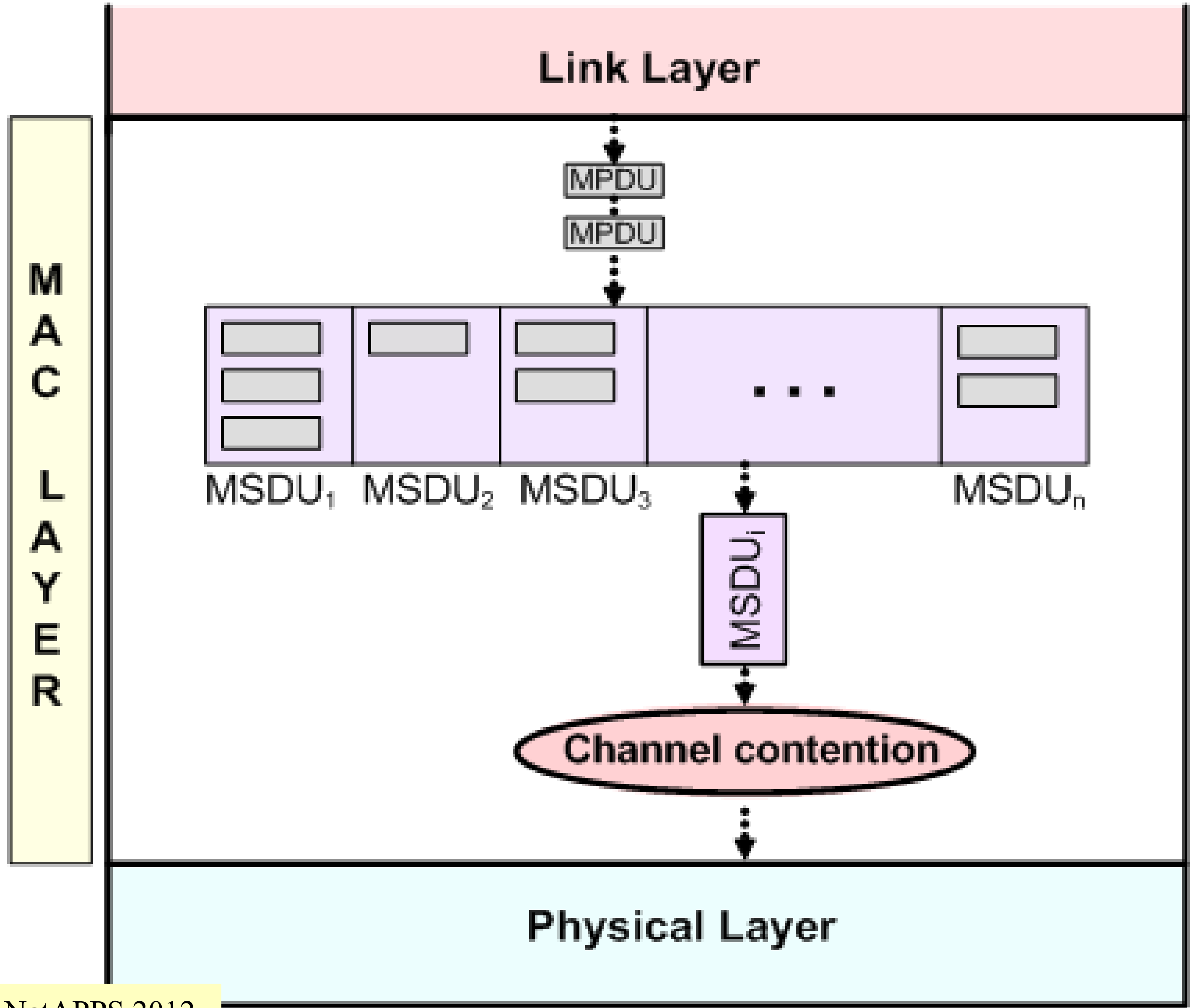
Sarkar, N.I. (2011) “Improving WLAN Performance by Modifying an IEEE 802.11 MAC Protocol” - IJWBT

Sarkar, N.I. and Sowerby, K.W. (2005) “Buffer Unit Multiple Access (BUMA) Protocol: an Enhancement to IEEE 802.11b DCF”– IEEE GLOBECOM’05.

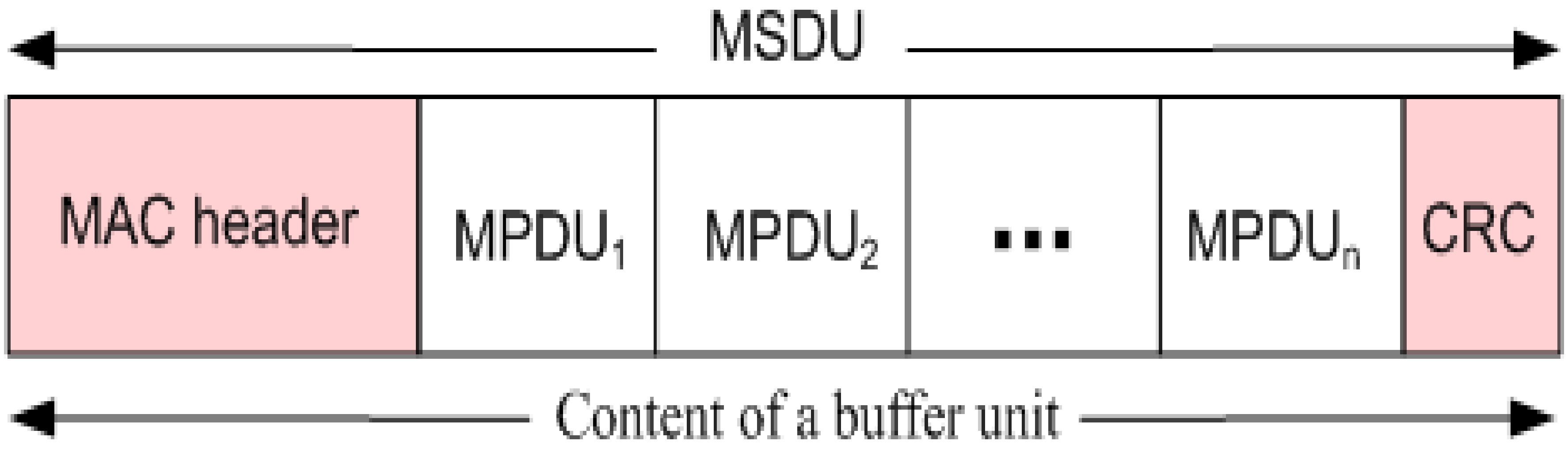
MAC design strategies



BUMA Architecture



Frame structure of BUMA

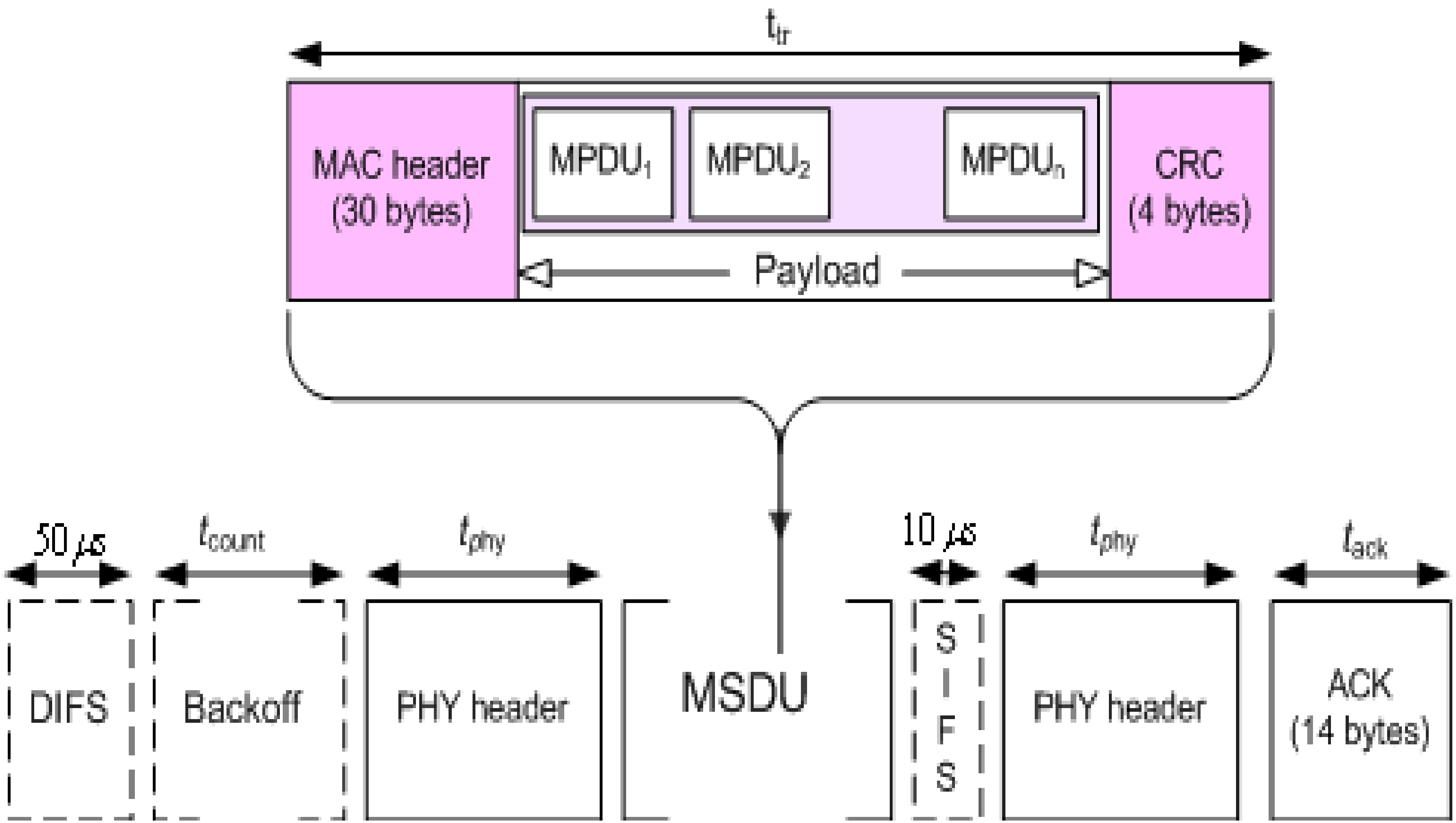


CRC: Cyclic Redundancy Check

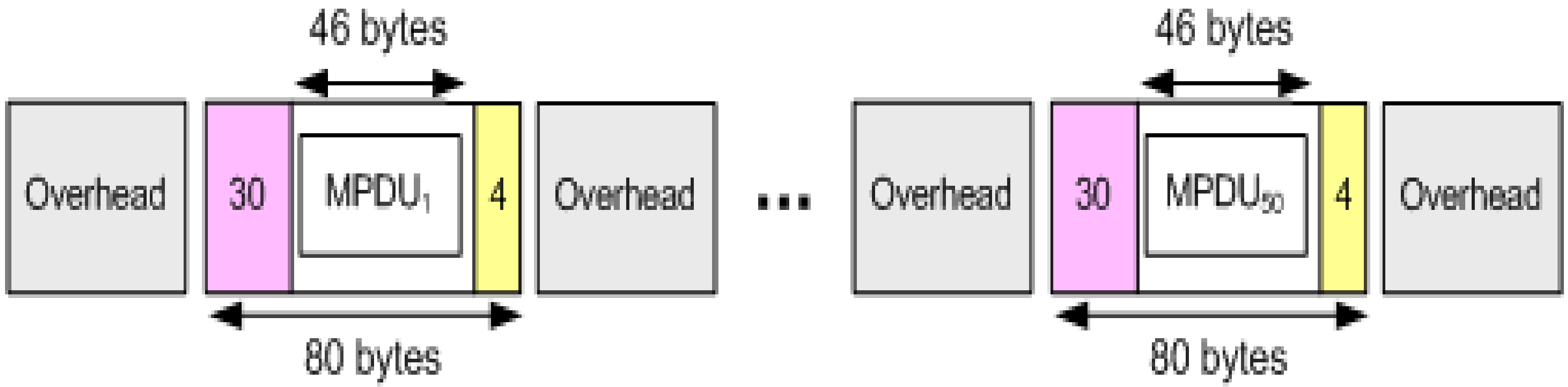
MPDU: MAC Protocol Data Unit

MSDU: MAC Segment Data Unit

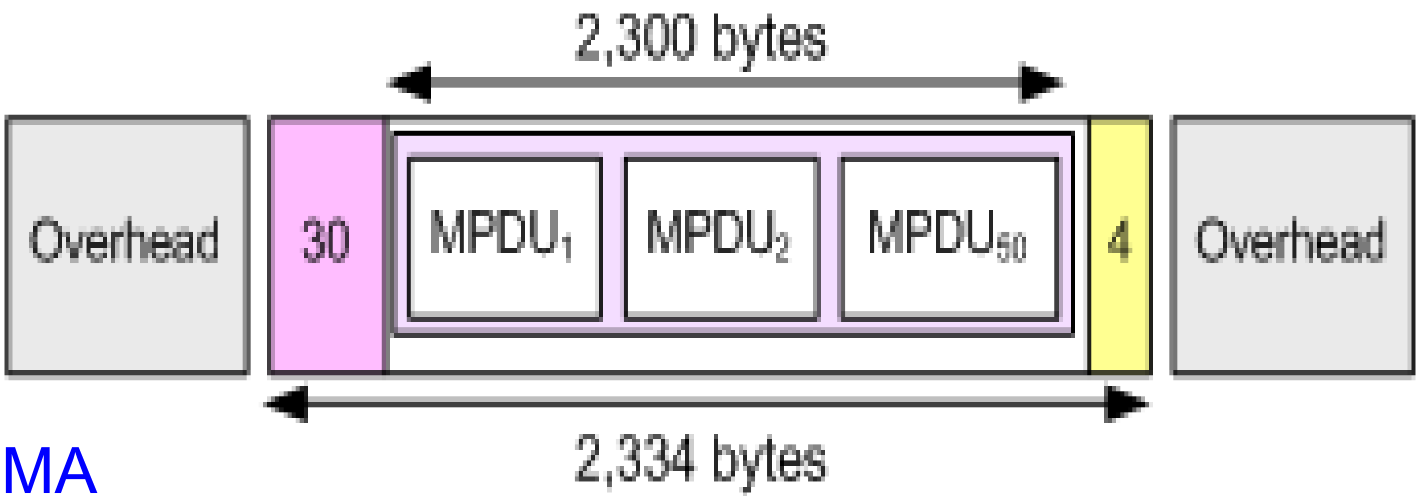
802.11 Overheads



Overhead: 802.11 DCF Vs BUMA



(a) 802.11 DCF



(b) BUMA

Example: Transmitting short packets

If a single user sends 56 bytes IP datagram over a 11 Mbps channel, the proportional throughputs achieved by:

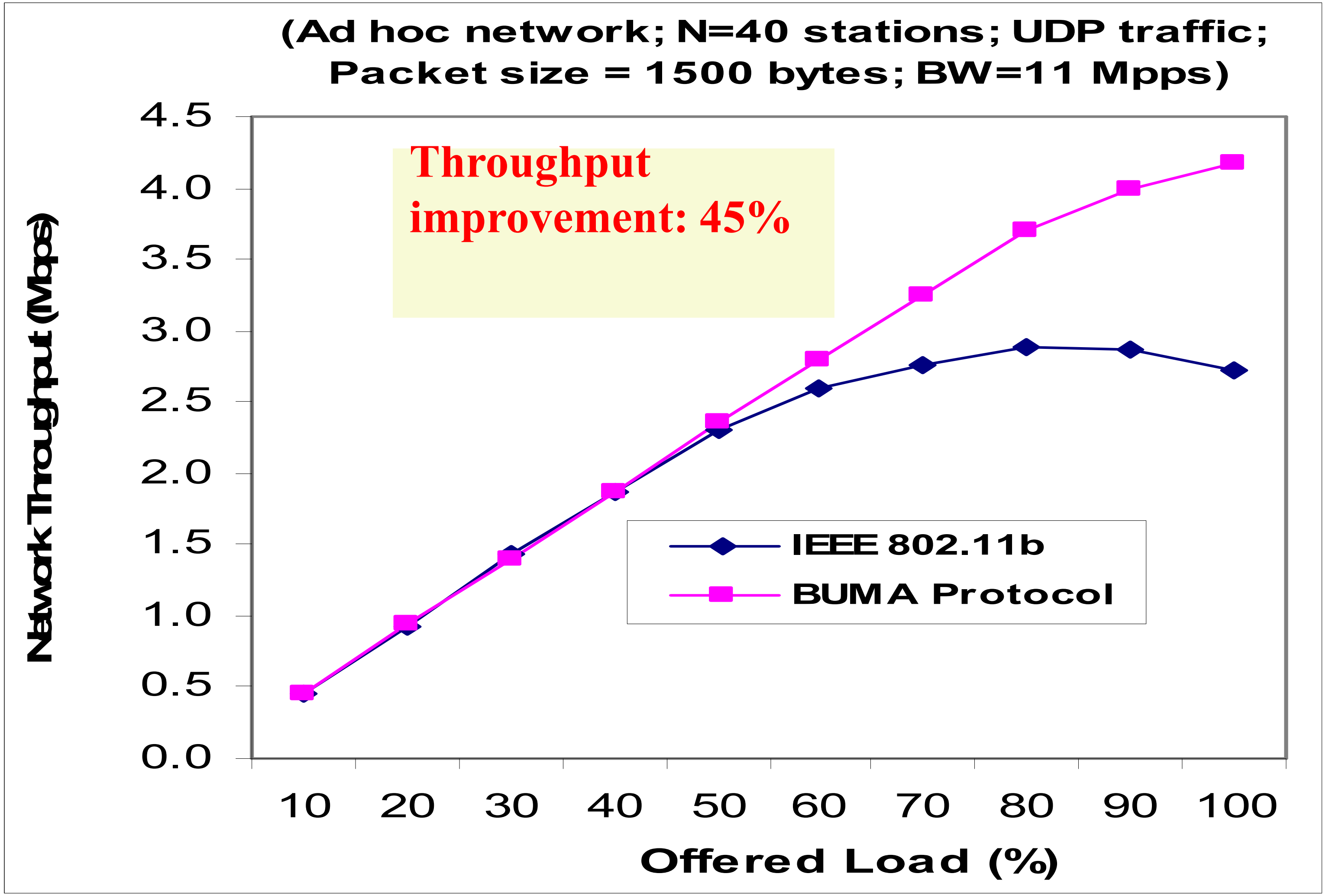
BUMA = 8.36 Mbps

802.11b DCF = 0.66 Mbps

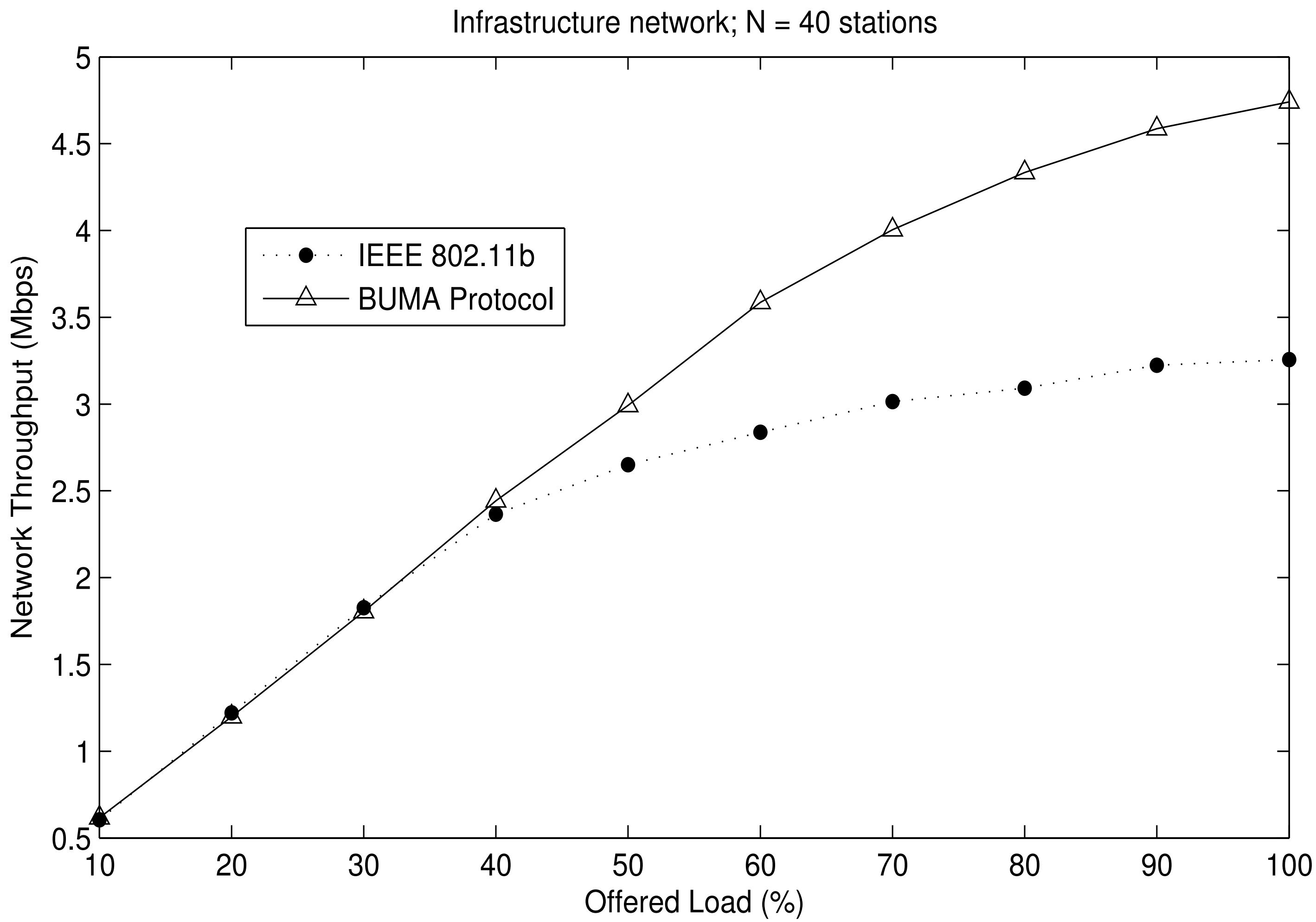
Transmission overhead comparison

IEEE 802.11b	BUMA Protocol
High	Low
↓	↓
High packet delay	Low packet delay

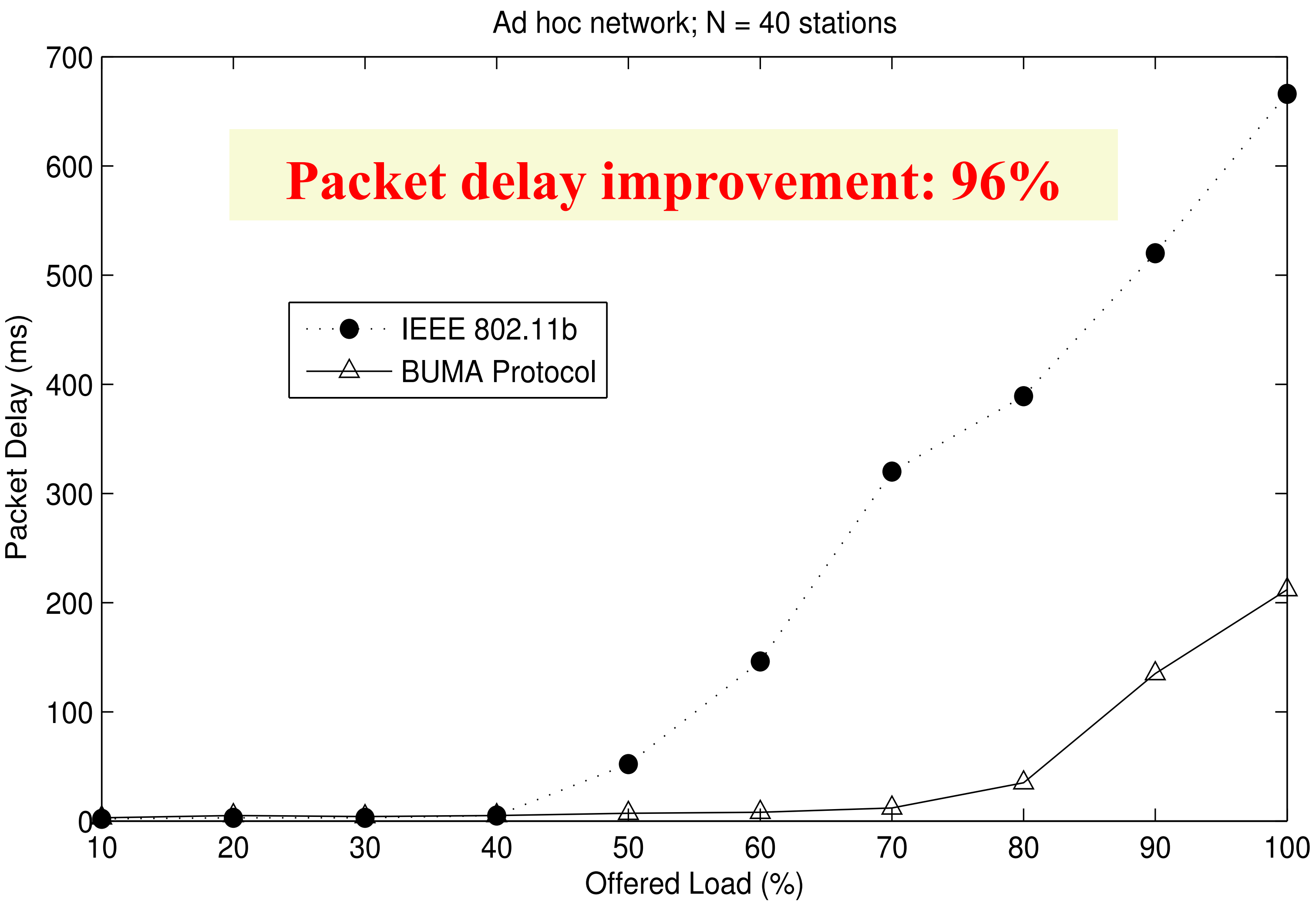
Throughput Vs. Offered load (Ad hoc network)



Throughput Vs. Offered load (Infrastructure network)

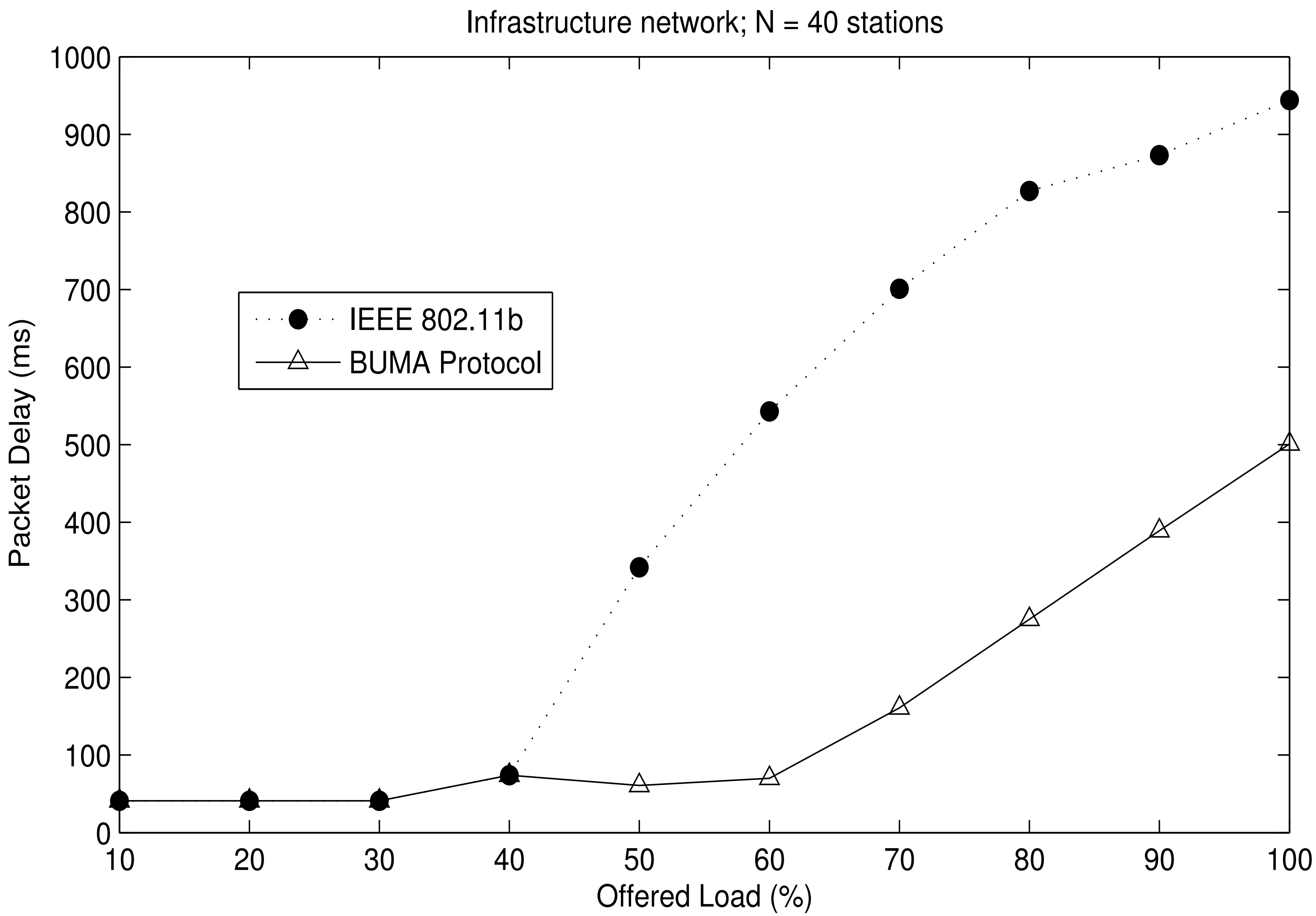


Packet delay Vs. Offered load (Ad hoc network)



Sarkar NetAPPS 2012

Packet delay Vs. Offered load (Infrastructure network)



IEEE 802.11 Vs. BUMA

IEEE 802.11b	BUMA Protocol
Low throughput	~ 45% higher throughput
High packet delay	~ 96 % lower delay
Simple	Simple and easy to implement

Improving 802.11 performance using cross-layer design optimization

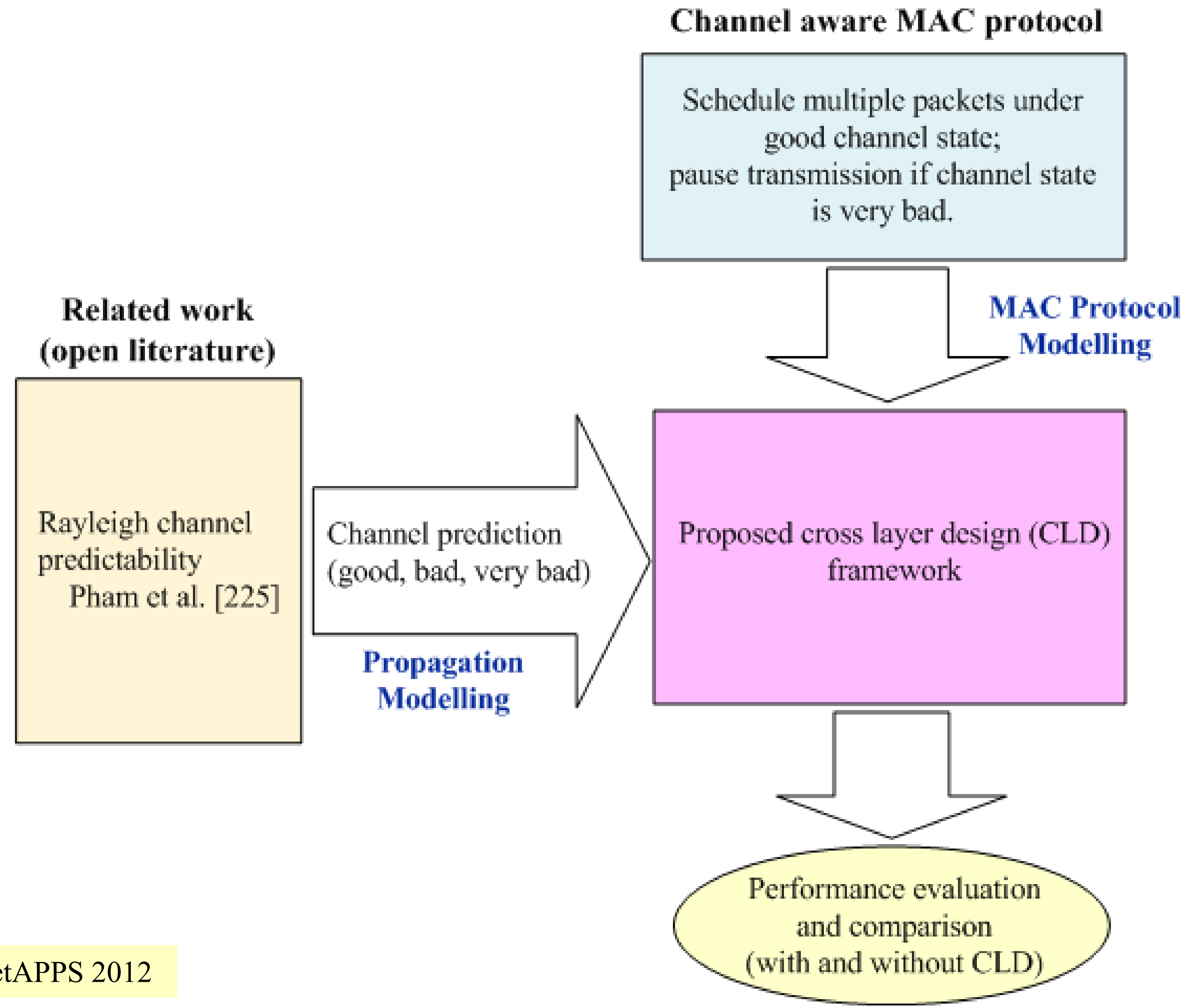
- We have developed a channel aware MAC protocol called C-BUMA .

- Key idea: Maximize packet transmission
  - » Send more data under good channel state
  - » Pause when channel state is very weak

Sarkar, N.I. (2010) "A Cross Layer Framework for WLANs: Joint Radio Propagation and MAC Protocol, ICCIT '10.

Sarkar, N.I. and Sowerby, K. (2006) "Joint Physical-MAC Layer Design Framework for Wireless LANs" - ICCT'06.

Cross-layer design approach



Performance improvement using CLD

Link (Source to destination)	Link throughput (Mbps)					
	TCP Traffic			UDP Traffic		
	CLD (Mbps)	Without CLD (Mbps)	Improvement (%)	CLD (Mbps)	Without CLD (Mbps)	Improvement (%)
0->1	0.179	0.162	**9.50**	0.308	0.24	**22.08**
0->2	0.187	0.163	**12.83**	0.444	0.36	**18.92**
2->3	0.117	0.077	**34.19**	0.512	0.478	**6.64**
3->4	0.038	0.017	**55.26**	0.49	0.476	**2.86**
4->5	0.254	0.216	**14.96**	0.36	0.308	**14.44**
4->6	0.204	0.165	**19.12**	0.404	0.343	**15.10**
5->6	0.1	0.08	**20.00**	0.22	0.187	**15.00**
5->7	0.09	0.06	**33.33**	0.344	0.308	**10.47**
6->7	0.17	0.12	**29.41**	0.47	0.267	**43.19**
Overall network	1.7	1.3	**40**	3.6	3	**60**

Outline of Talk

- ✓ Factors Influencing WLAN Performance
- ✓ Methods of Improving WLAN
- o WLAN Deployment Guidelines
- o Conclusions

WLAN Deployment Guidelines

- **WLAN Deployment Scenarios**
  - Single floor office scenario
  - Multi-floor office scenario
  - Computer laboratory
  - Residential house environment
- **Deployment Guidelines**

➢ Find an optimum AP position that provides a better coverage and performance.

➢ Estimate the number of wireless clients that an AP can support.

Outline of Talk

- ✓Factors Influencing WLAN Performance
- ✓Methods of Improving WLAN
- ✓WLAN Design Guidelines
- o Conclusions

Summary and conclusions

- The key factors influencing WLAN performance have been quantified.
- BUMA protocol offers significantly better delay and throughput performance than 802.11 DCF.
- Signal blockage by walls and floors was found to have a significant effect on 802.11 throughput.
- Minimum two APs are required (one for each region) to cover the WY office floor.
- WLAN throughput can be optimized by carefully configuring and placing APs.

Future research directions

- Rate adaptation QoS-aware MAC protocol design for multimedia WLANs.
- Cross-layer design with adaptive payload and rate adaptation for multimedia WLANs.
- Development of an adapting routing protocol for WLANs.
- Development of antenna-aware propagation models.

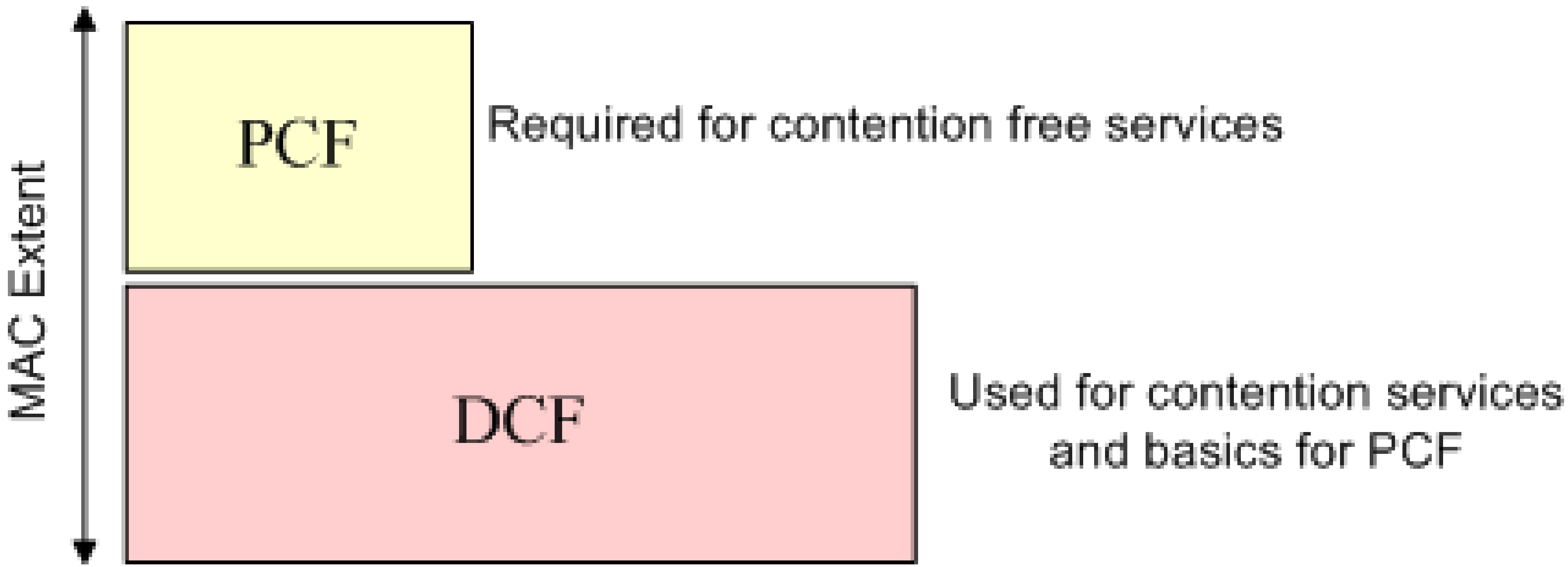
Thank you for your attention

Terima kasih

با تشکر از توجه شما

nurul.sarkar@aut.ac.nz

IEEE 802.11 MAC Architecture



DCF: Distributed coordination function
PCF: Point coordination function

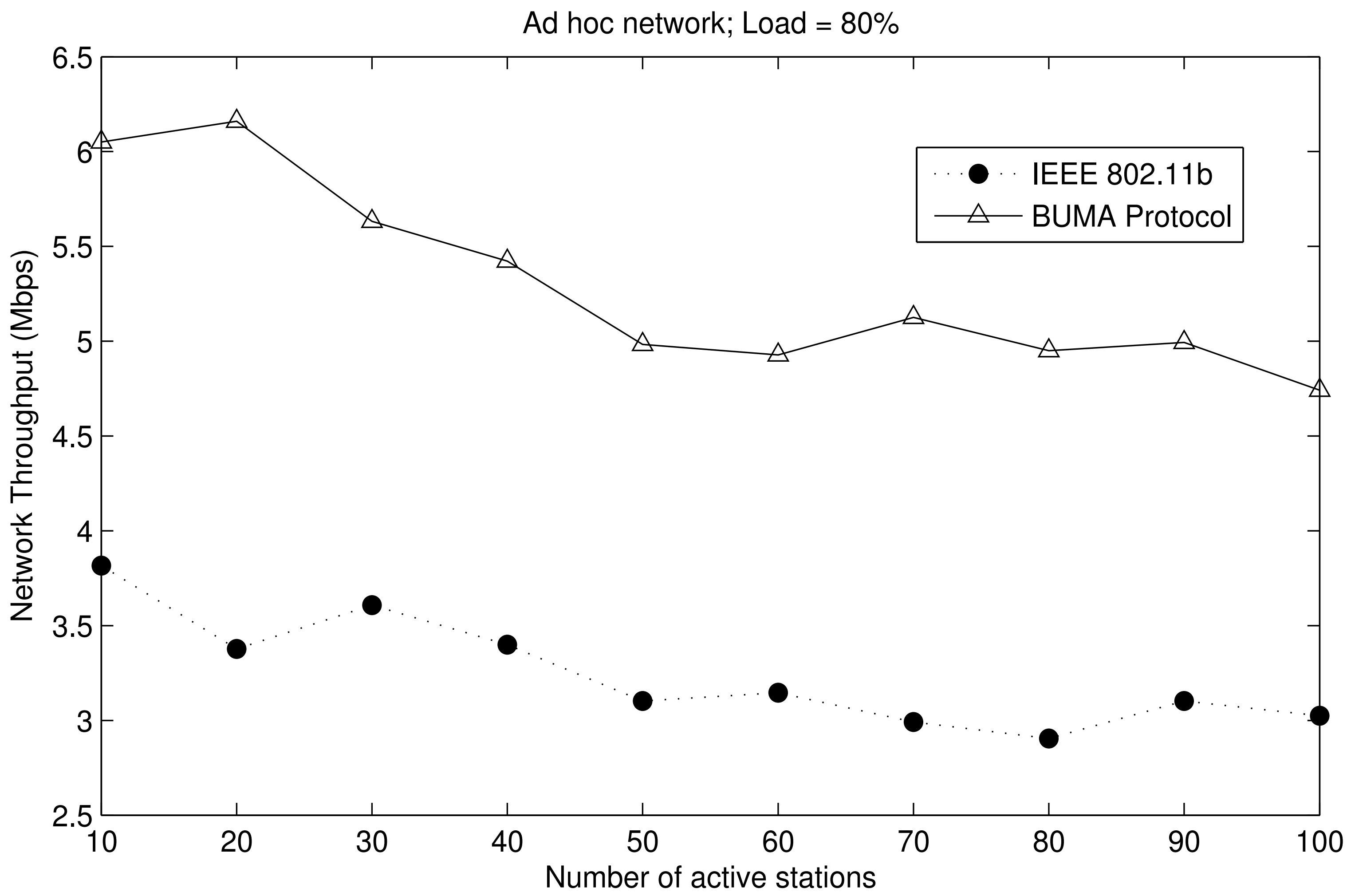
Buffer unit size optimisation

Buffer unit size (packet)	*Offered load (%)*	*Throughput (Mbps)*	*Delay (ms)*
1	70	4.03	887
2	70	5.76	665
3	70	6.66	399
4	70	6.19	638
10	70	6.84	625
100	70	6.89	1464

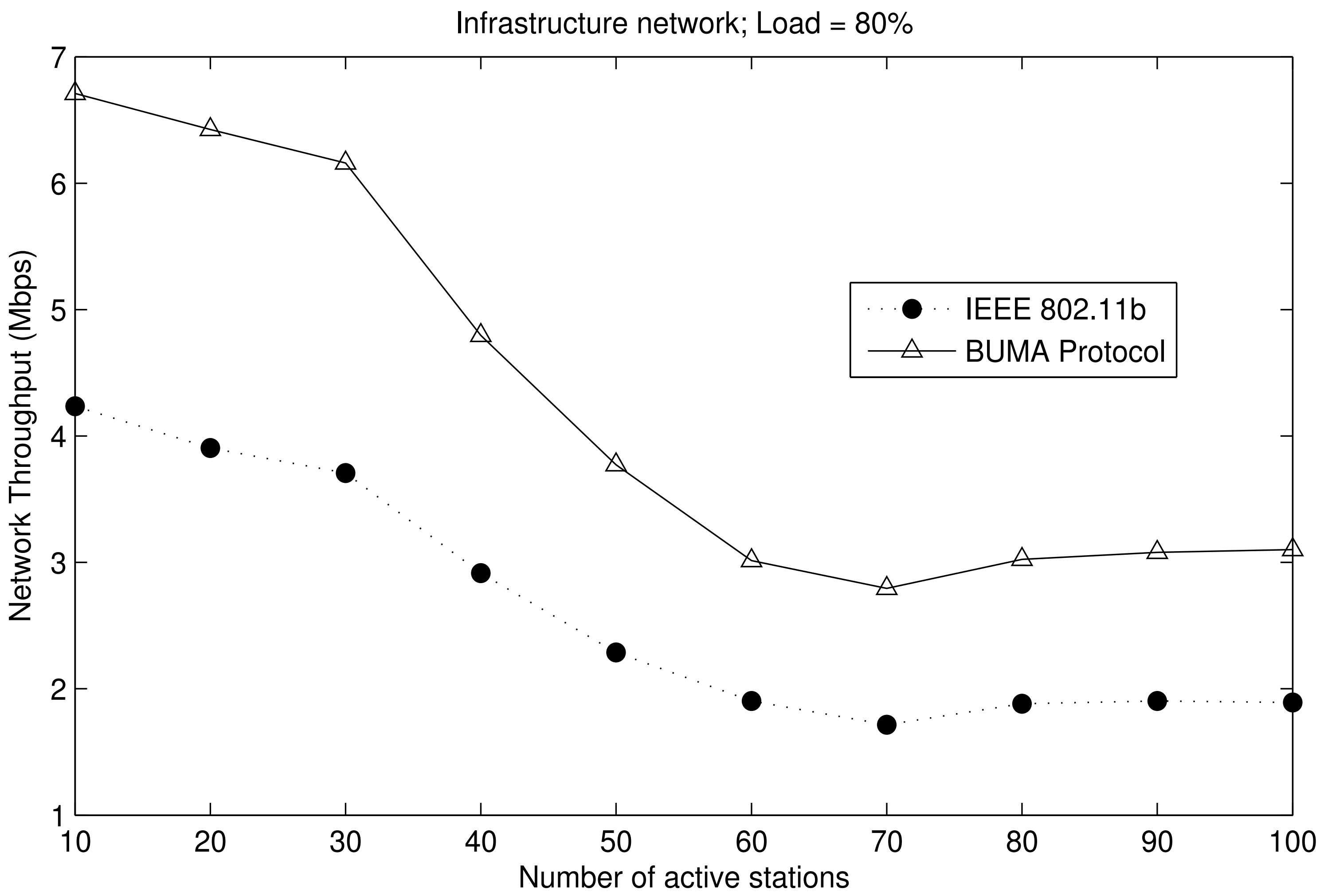
Ns-2 simulation parameters

Parameter	Value
Data rate	11 Mbps
Basic rate	2 Mbps
Wireless card	802.11b
Slot duration	20 μs
SIFS	10 μs
DIFS	50 μs
MAC header	30 bytes
CRC	4 bytes
PHY header	96 μs
Traffic	TCP and UDP
Data packet length	1500 bytes
Channel model	Two-ray ground
RTS/CTS	Off
PHY modulation	DSSS
CWmin	31
CWmax	1023
Simulation time	10 minutes

Throughput Vs. Stations (Ad hoc network)



Throughput Vs. Stations (Infrastructure network)



Packet delay Vs. Stations (Ad hoc network)