QoS-Supported WLAN and Multimedia Service

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WLAN for Multimedia Today?

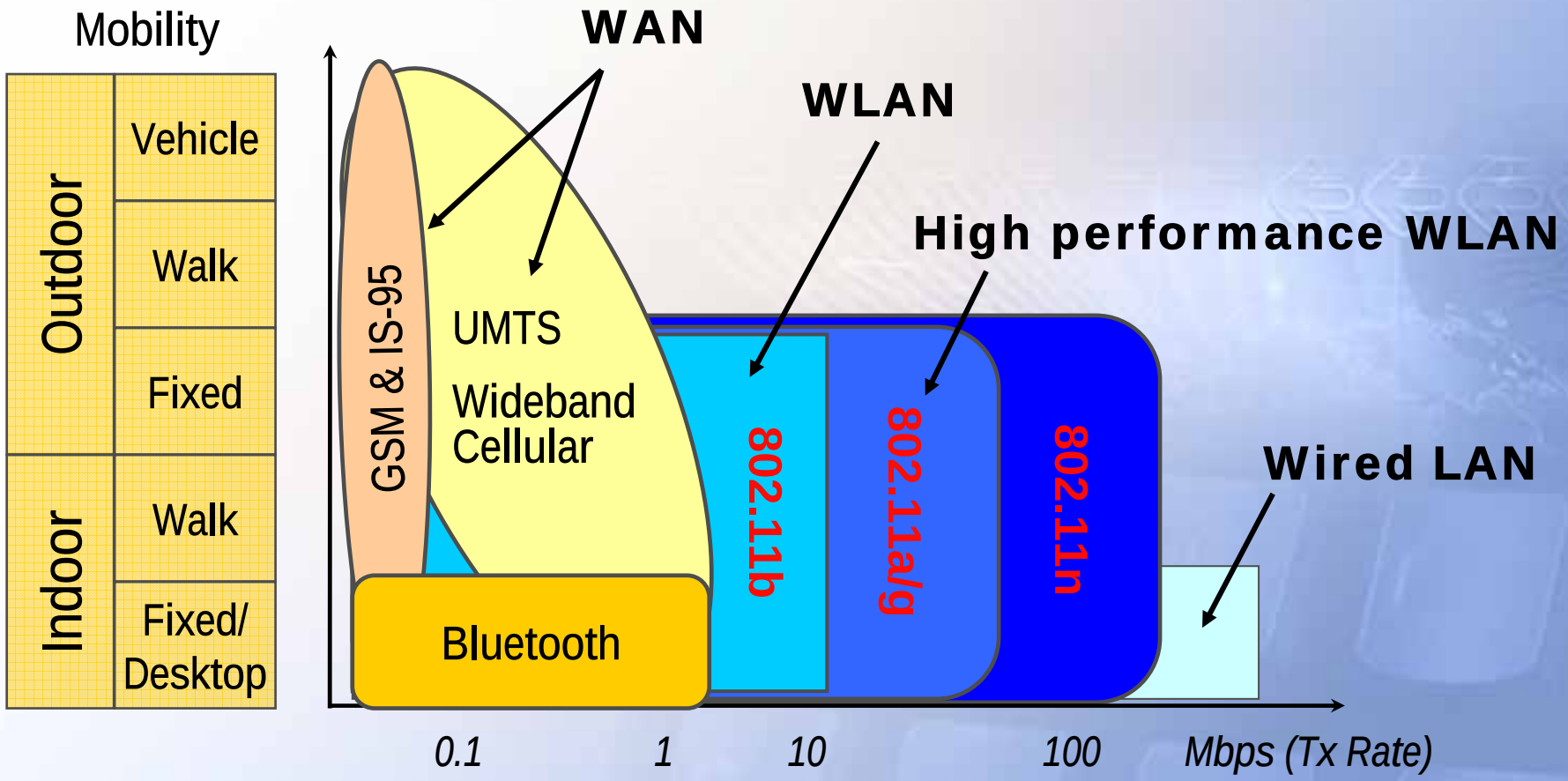
- Lack of QoS support
  - Only good for best-effort traffic
- Limited capacity (or throughput)
  - Due to high protocol overhead
  - ~25 Mbps throughput with 11a/g 54 Mbps tx rate

→ Emerging 11e and 11n will help!

Talk Outline

- Introduction to IEEE 802.11 WLAN
- Baseline MAC of IEEE 802.11
- IEEE 802.11e for QoS
- IEEE 802.11n for high throughput
- Conclusion

WLAN vs. Other Solutions



Typical Home Networking with Ethernet

Wireless Home Networking:
Today with Wireless Ethernet

Wireless Home Networking:
Tomorrow with 802.11e WLAN

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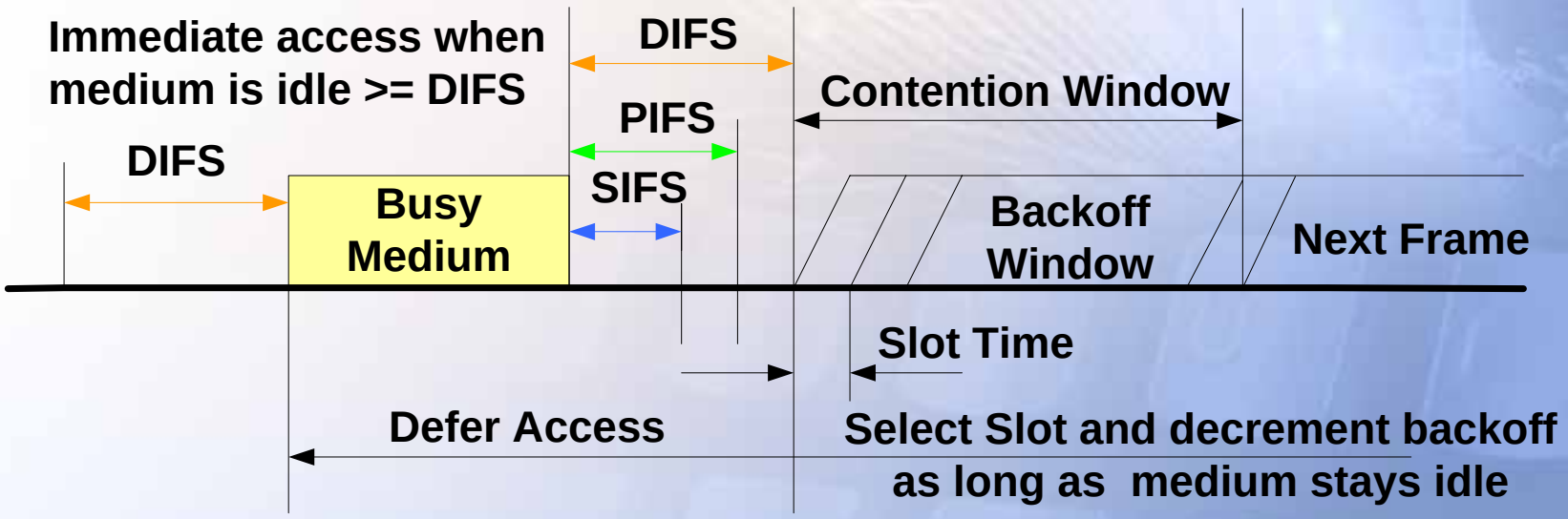
Baseline MAC Description

Two Coordination Functions

- *Mandatory* Distributed Coordination Function (DCF)
  - For distributed contention-based channel access
- *Optional* Point Coordination Function (PCF)
  - For centralized contention-free channel access
- DCF only for most commercial 802.11 devices

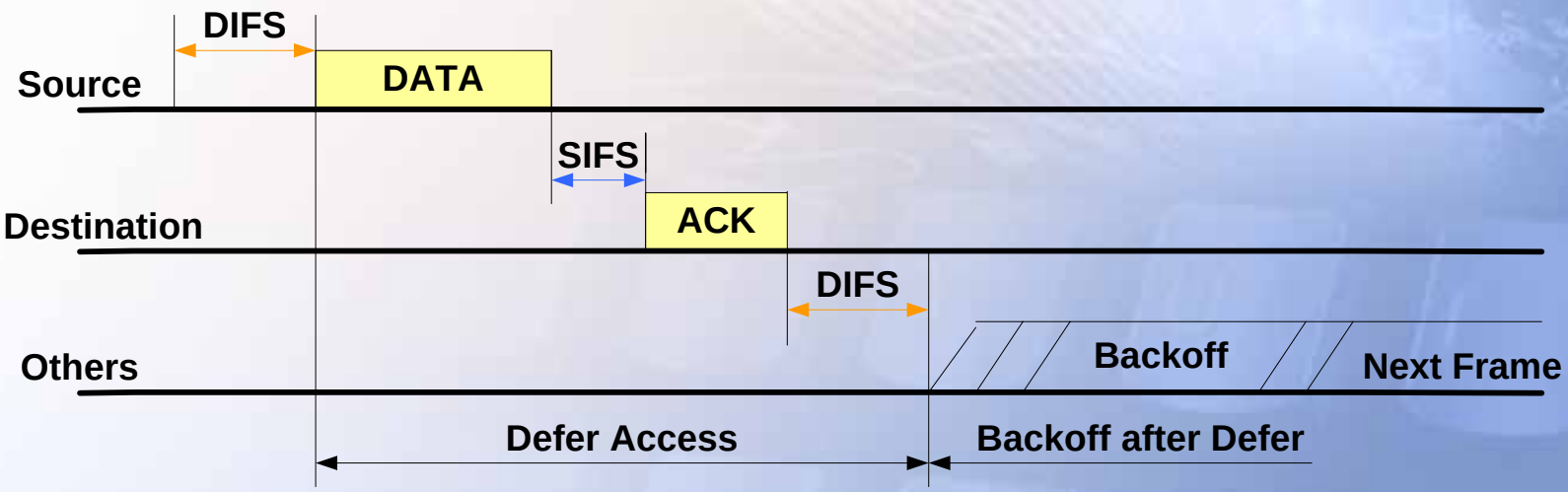
Distributed Coordination Function (DCF)

- Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)
  - similar to IEEE 802.3 Ethernet CSMA/CD



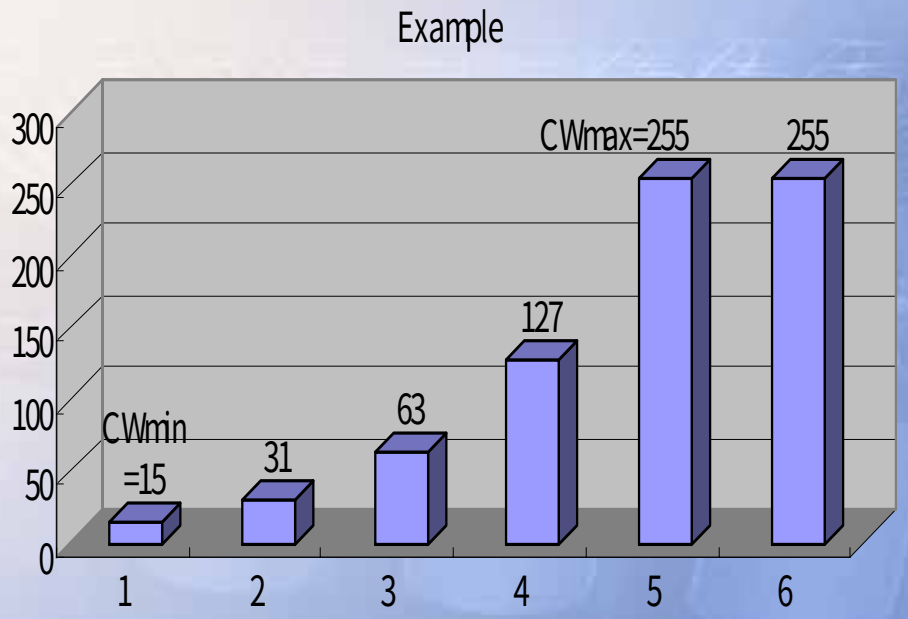
Stop-and-Wait ARQ

- Receiver of a directed frame returns an ACK
- If ACK not received, sender retransmits after another backoff



Binary Exponential Backoff

- Backoff Counter is randomly selected from [0,CW], where CW is contention window
- For each unsuccessful frame transmission, CW doubles (from CWmin to CWmax)
- CW ← 2 (CW+1)-1
- Reduces the collision probability



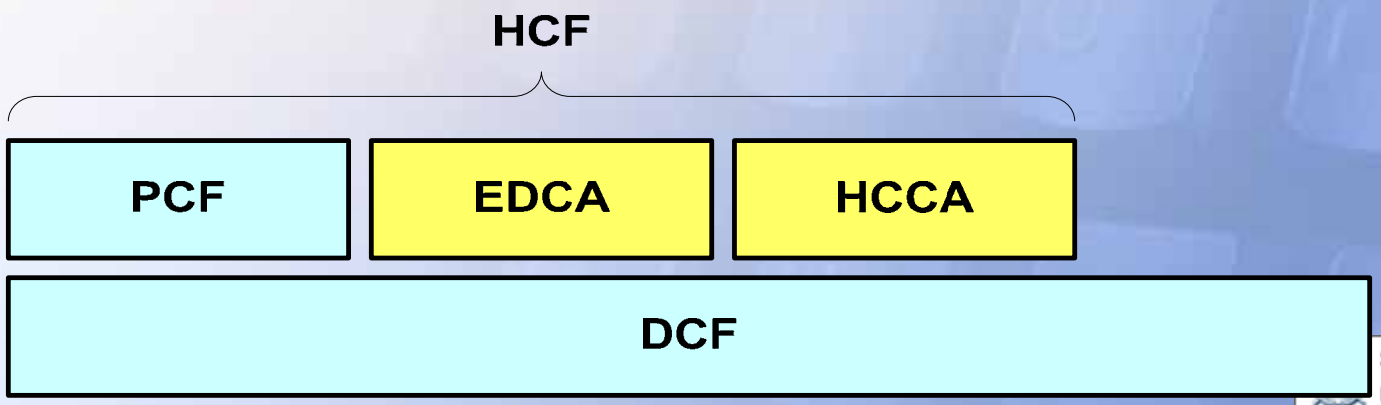

IEEE 802.11e EDCA

Prioritized vs. Parameterized QoS

- Prioritized QoS (like DiffServ)
  - Differentiated channel access for frames with different user priorities
  - 8 different user priorities (Ups)
  - 802.1d bridge supports similar concept
- Parameterized QoS (like IntServ)
  - QoS is characterized by a set of parameters
  - A traffic stream (TS) is set up between transmitter and receiver (and QoS AP or QAP)

Hybrid Coordination Function (HCF)

- Two access mechanisms
- Contention-based channel access
  - Enhanced Distributed Channel Access (EDCA)
  - Variation of legacy DCF
- Controlled channel access
  - HCF Controlled Channel Access (HCCA)
    - Polling mode plus HC's prioritized channel access mainly
  - Variation of legacy PCF

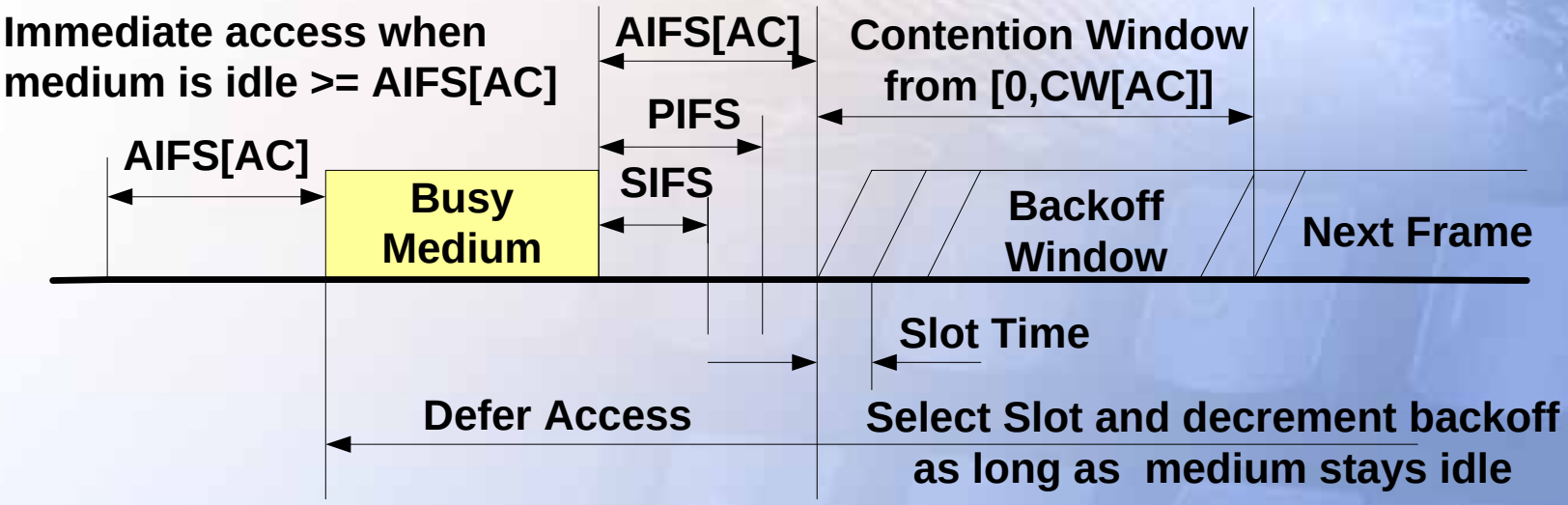


User Priority to Access Category Mapping

Priority	User Priority (UP - Same as 802.1D User Priority)	802.1D Designation	Access Category (AC)	Designation (Informative)
Lowest ↓ Highest	1	BK	AC_BK	Background
	2	-	AC_BK	Background
	0	BE	AC_BE	Best Effort
	3	EE	AC_BE	Best Effort
	4	CL	AC_VI	Video
	5	VI	AC_VI	Video
	6	VO	AC_VO	Voice
	7	NC	AC_VO	Voice

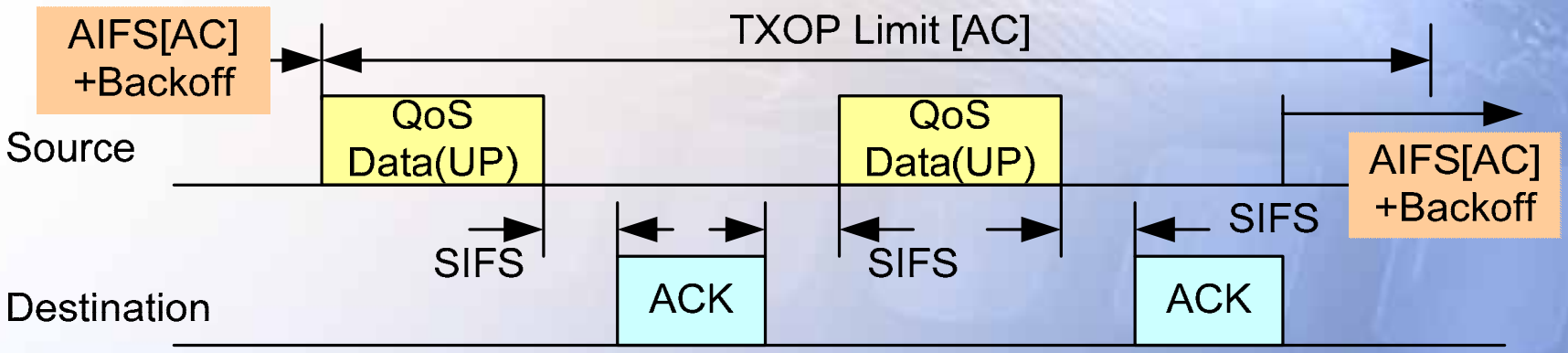
Prioritized Channel Access

- Each channel access function contends with
  - AIFS[AC] (instead of DIFS) and CW[AC] (instead of CW)



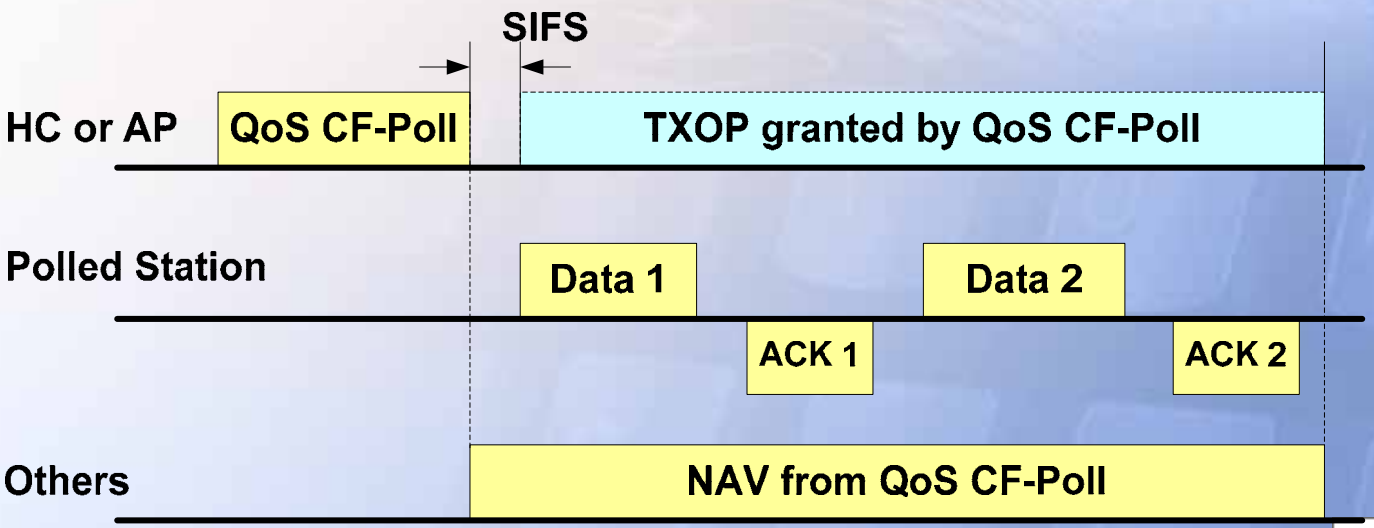
EDCA TXOP

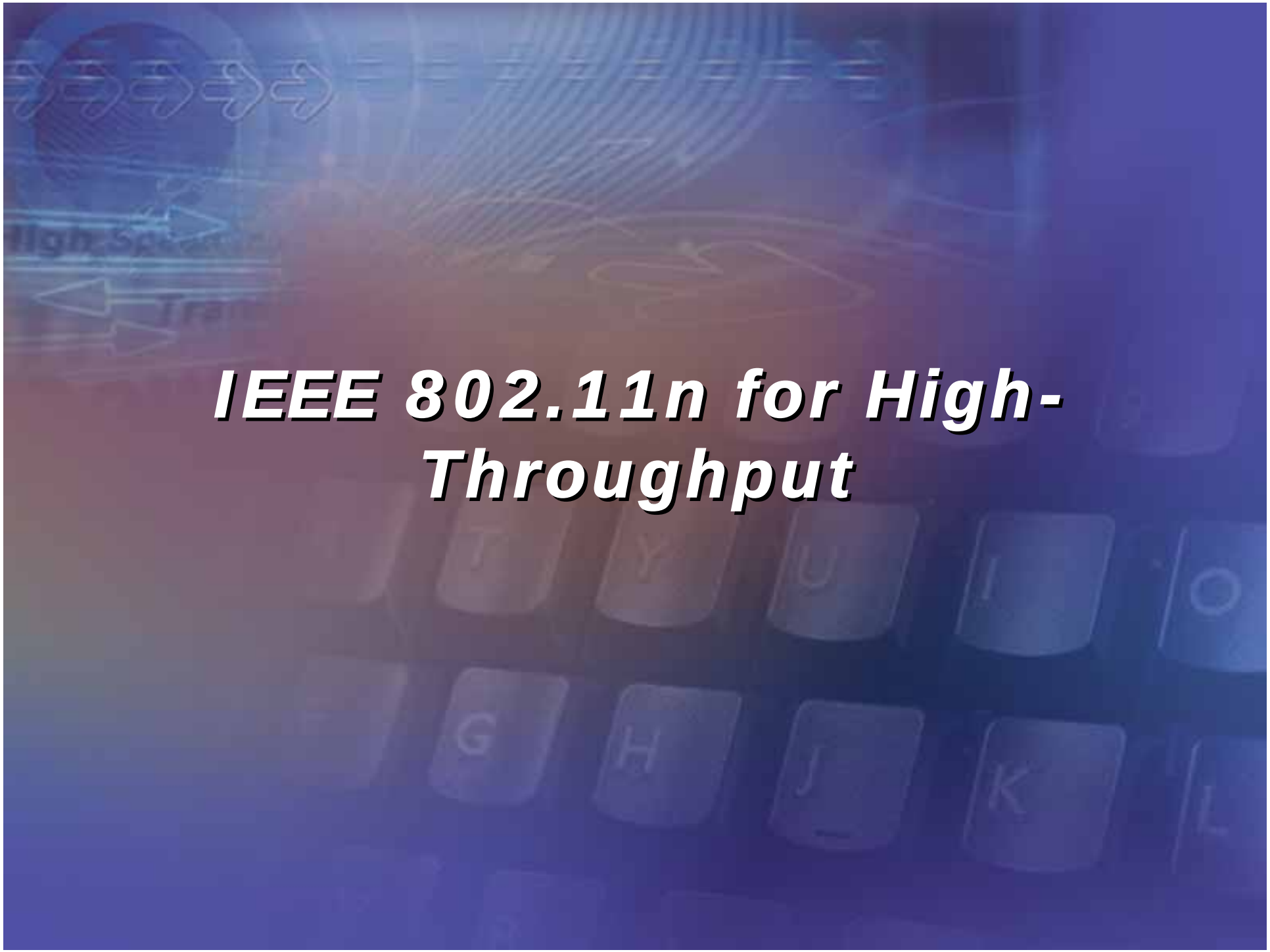
- Within an EDCA TXOP
  - multiple frames from the AC *can* be transmitted with the limit of TXOPLimit[AC]
  - Ends if a frame transmission fails!



HCCA TXOP

- Polling frame can be transmitted according to AP's scheduling
  - after PIFS idle time in case of CP
- Polling frame carries Dur/ID covering TXOP
  - During a polled TXOP, the TXOP holder can transmit whatever frames it wants
  - Different from EDCA TXOP



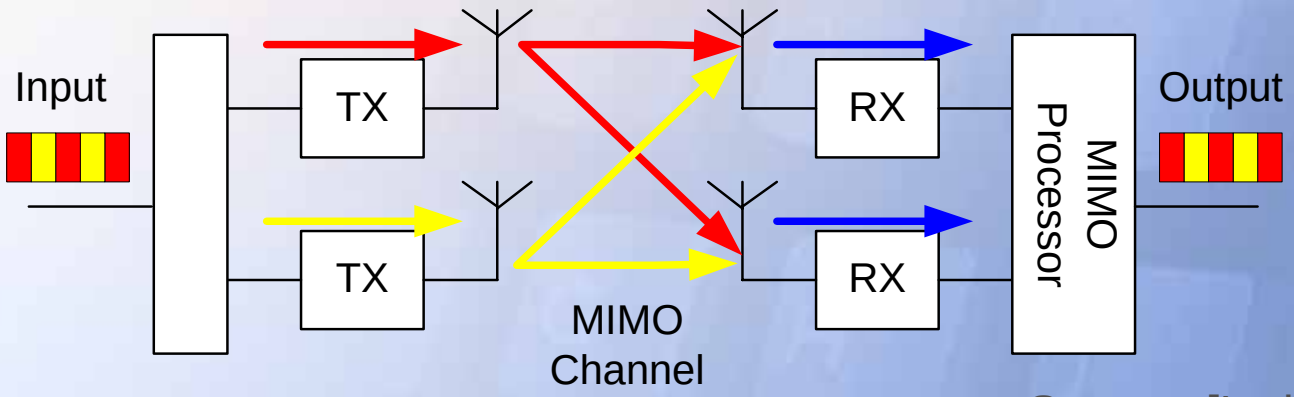

IEEE 802.11n for High-Throughput

802.11n for Higher Throughput

- To provide higher throughput, i.e., > 100 Mbps, at MAC SAP
- Enhance both OFDM PHY and MAC
  - Make the current MAC more efficient
  - Add MIMO (SDM, STC, beamforming), channel bonding, etc. to PHY
- Status:
  - Proposals made in Sept. 2004
  - As of March 2005, one pending proposal
  - TGn Sync

11n PHY Candidate Techniques

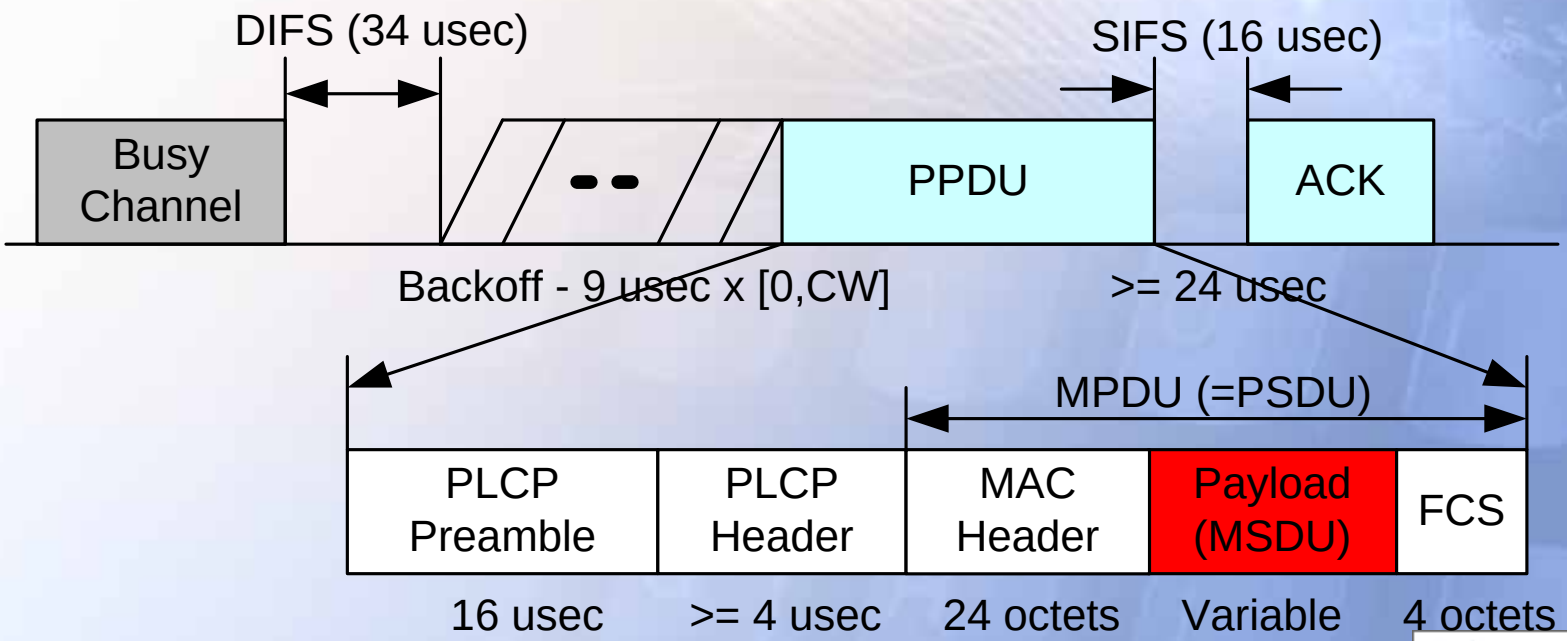
- Channel bonding
  - Using 40MHz instead of 20MHz (of 11a)
- Multi-Input Multi-Output (MIMO)
  - Spatial channels of different antenna pairs are often uncorrelated
- Up to ~600 Mbps rate proposed
  - Using 4x4 40 MHz channel



Source: [Insider04]

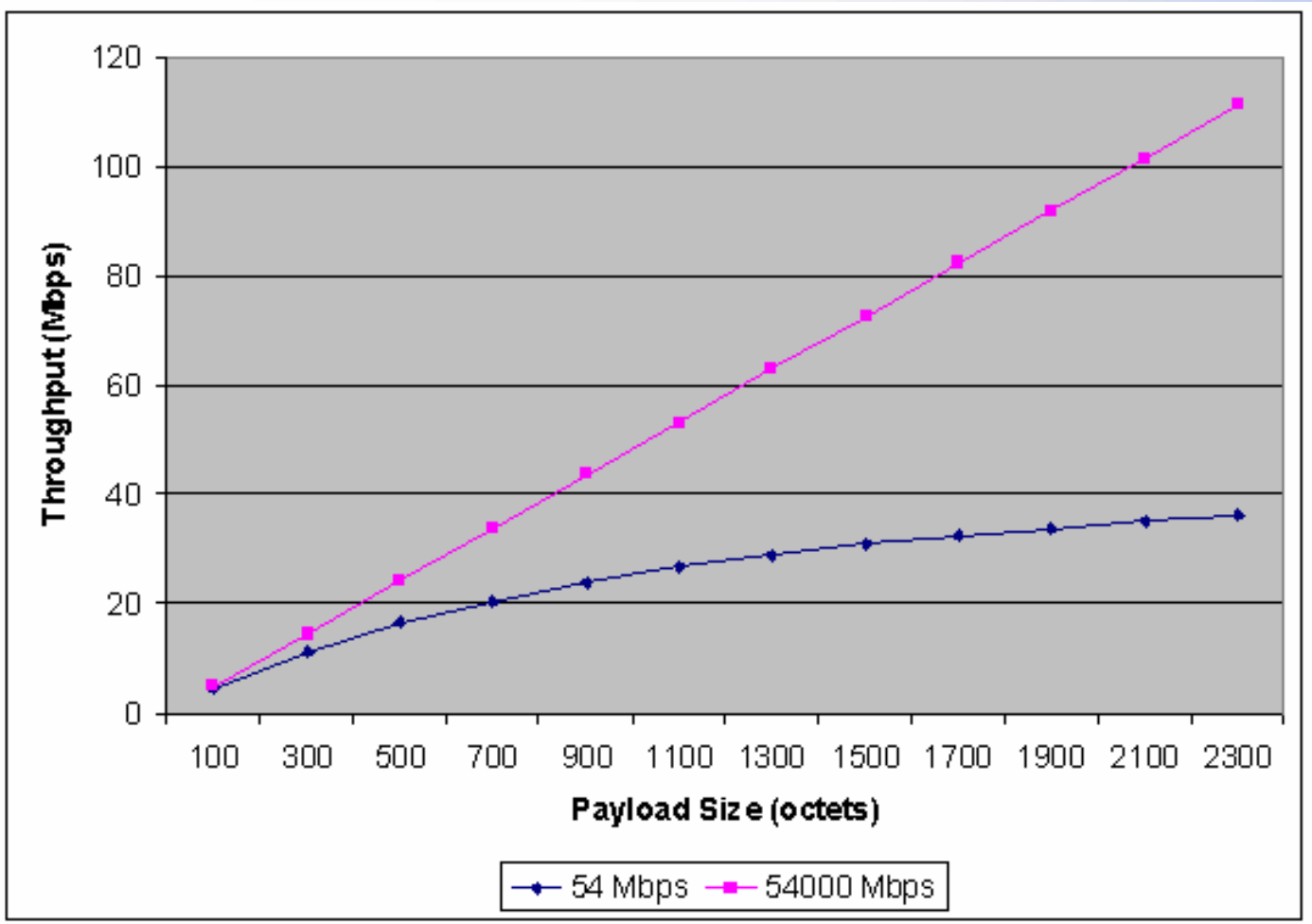
Why is Legacy MAC limited?

- (DCF) with lots of overheads related to PHY and MAC
  - Preamble, PHY & MAC headers, backoff, IFSs, and ACK
  - See below for .11a



Throughput vs. Payload Size

Ref: [Yang02]



- .11a & DCF theoretical throughput: ~110 Mbps with max payload=2304 octets & 5400 Mbps TX rate

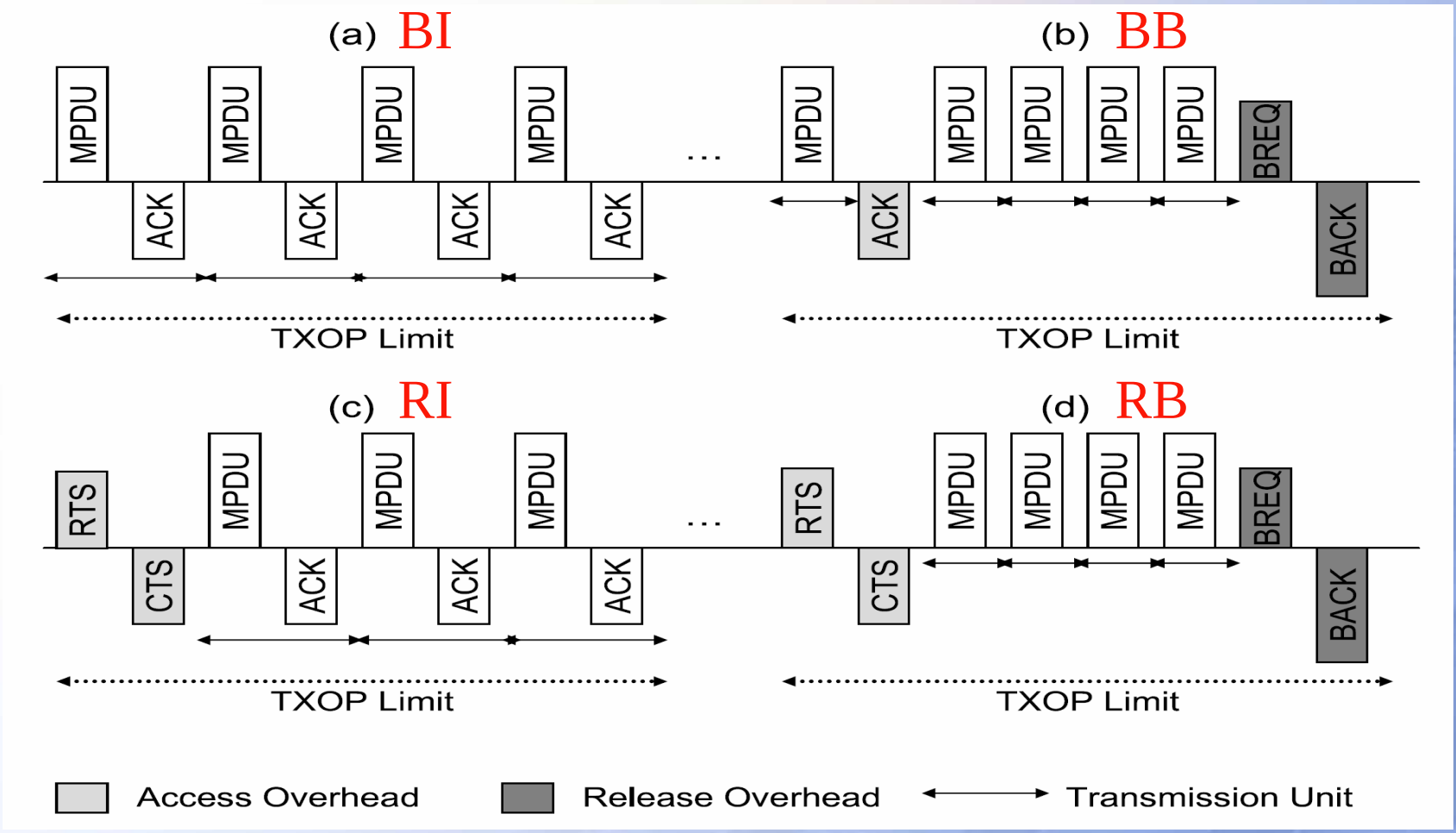
Key Techniques for 11n MAC:
- 802.11e TXOP and Block ACK
- Frame Aggregation

Ref: [Tinnirello05], [Kim04]

802.11e TXOP and Block ACK

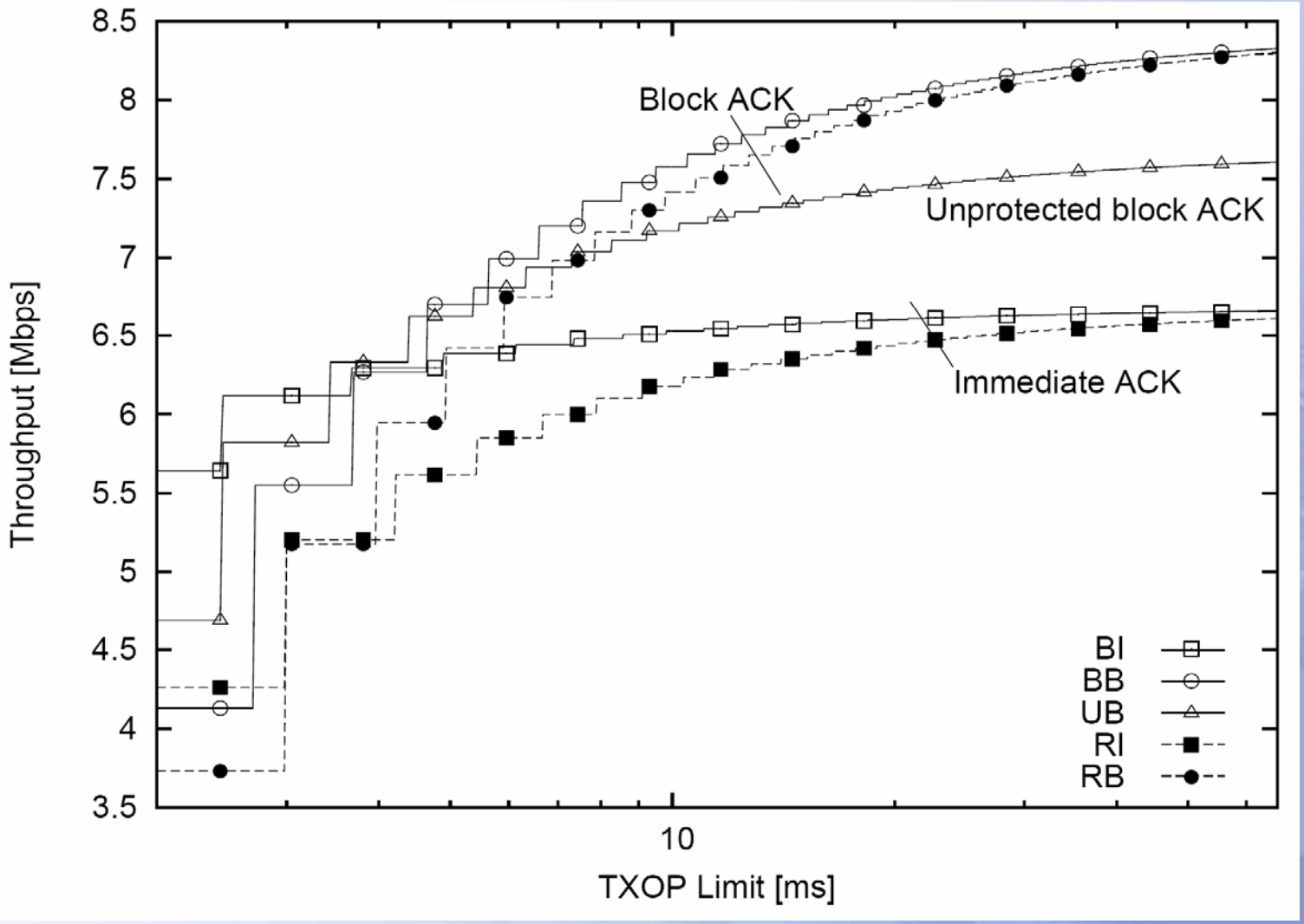
- Transmission Opportunity (TXOP)
  - Multiple MPDUs (or MSDUs) can be transmitted back-to-back per a channel access
- Block ACK
  - Instead of immediate ACK
  - Block ACK from receiver after a number of MPDUs from transmitter
  - Allowing selective ARQ

Different Access Modes and ACK Policies



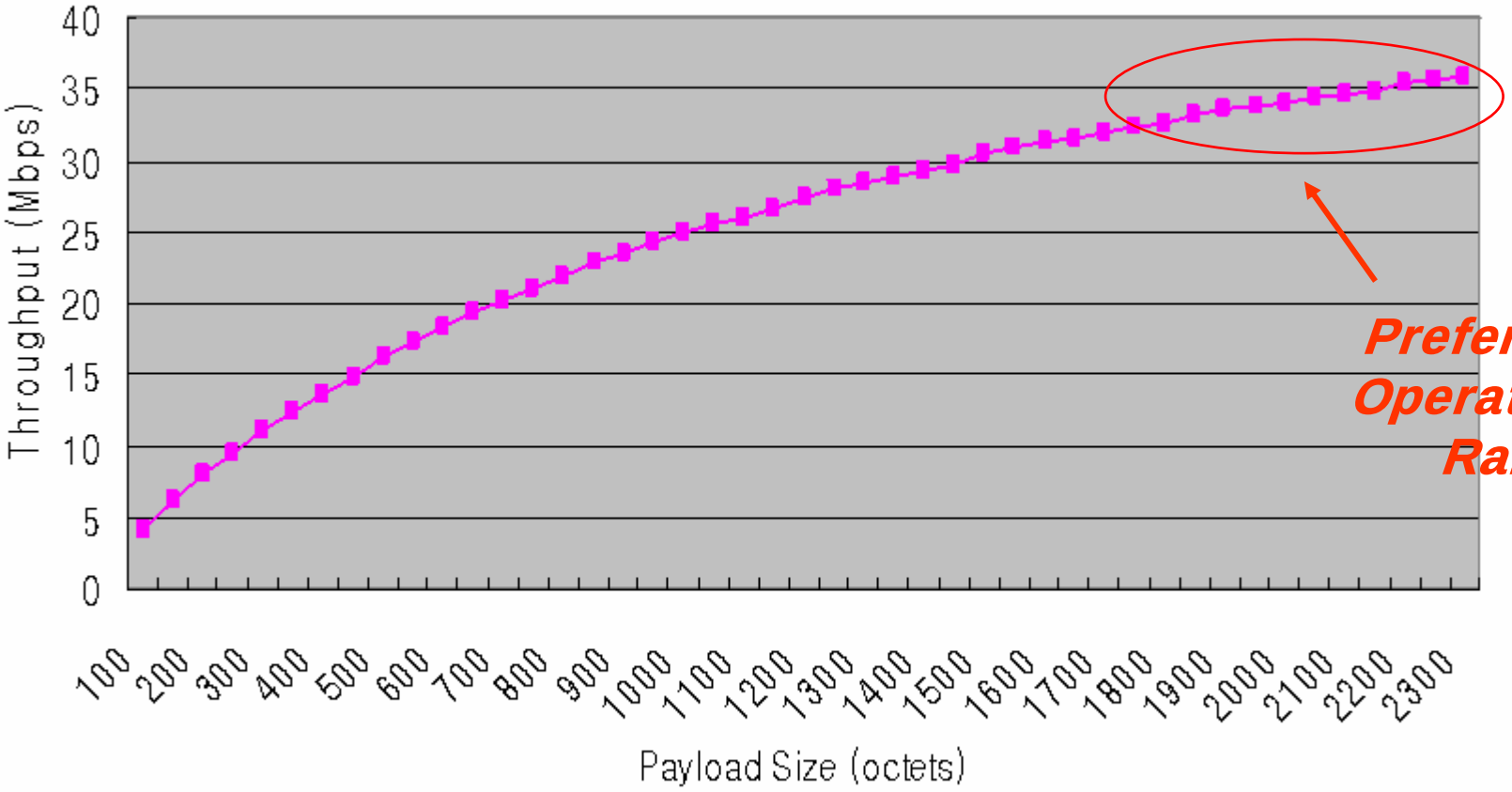
Throughput vs. TXOP Limit

Ref: [Tinnirello05]

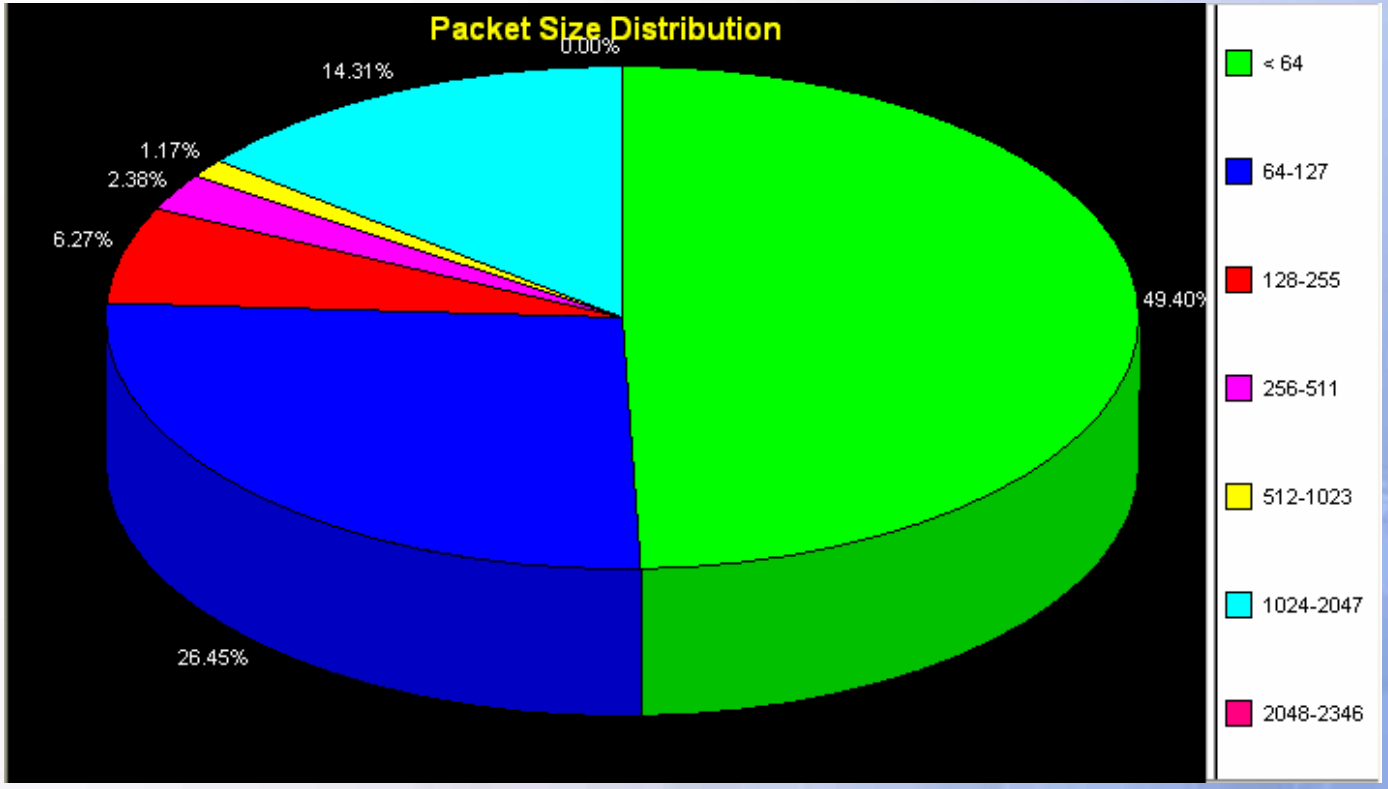


- .11b 11Mbps, no channel error, 5 STAs

Theoretical Throughput



Packet Size Statistics

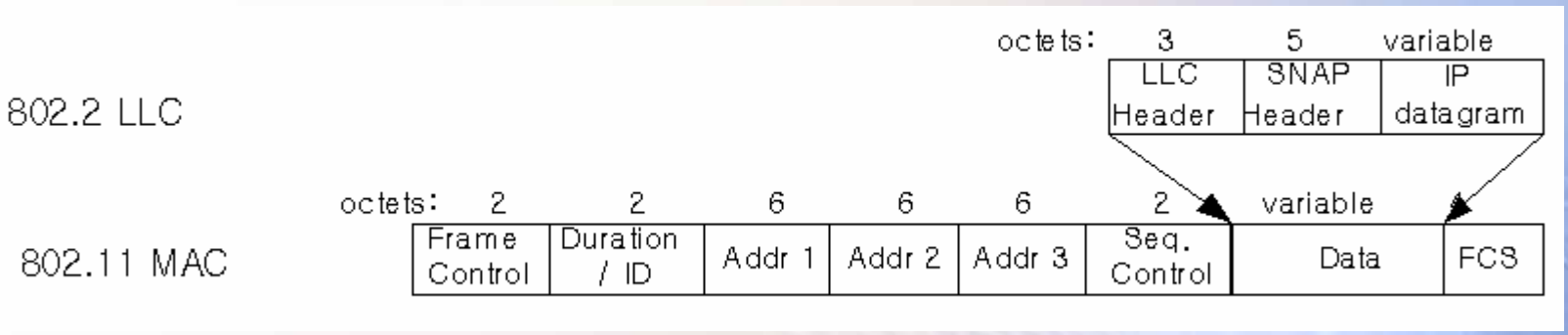


This statistics is from the measurement taken
in IEEE 802.11 standard meeting
in the morning of July 22nd 2003

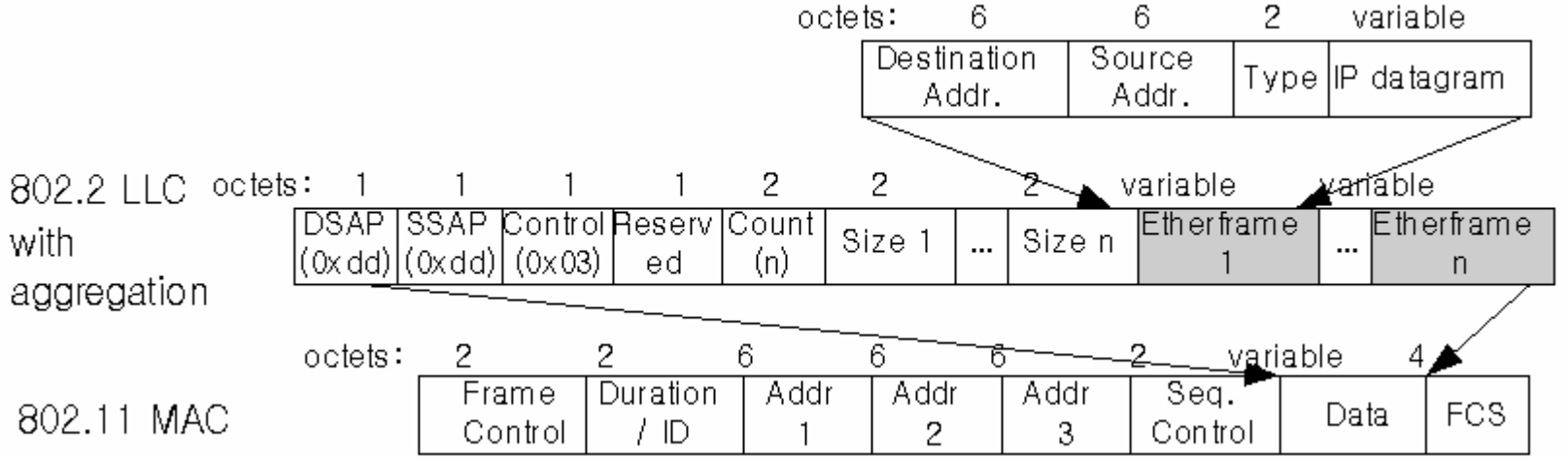
Frame Formats (Example)

Ref: [Kim04]

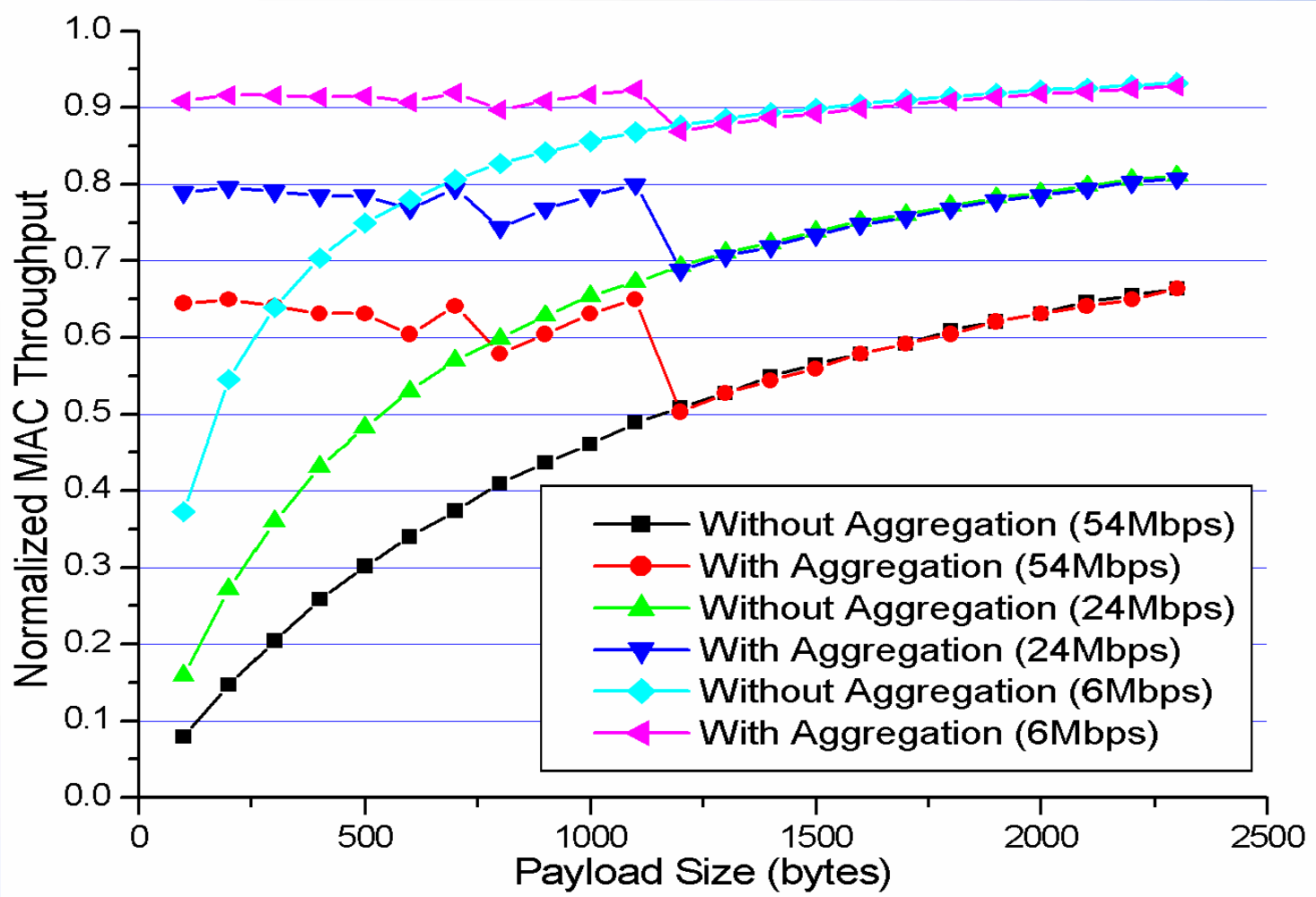
Original



With aggregation



Throughput vs. Payload via Frame Aggregation Ref: [Kim04]



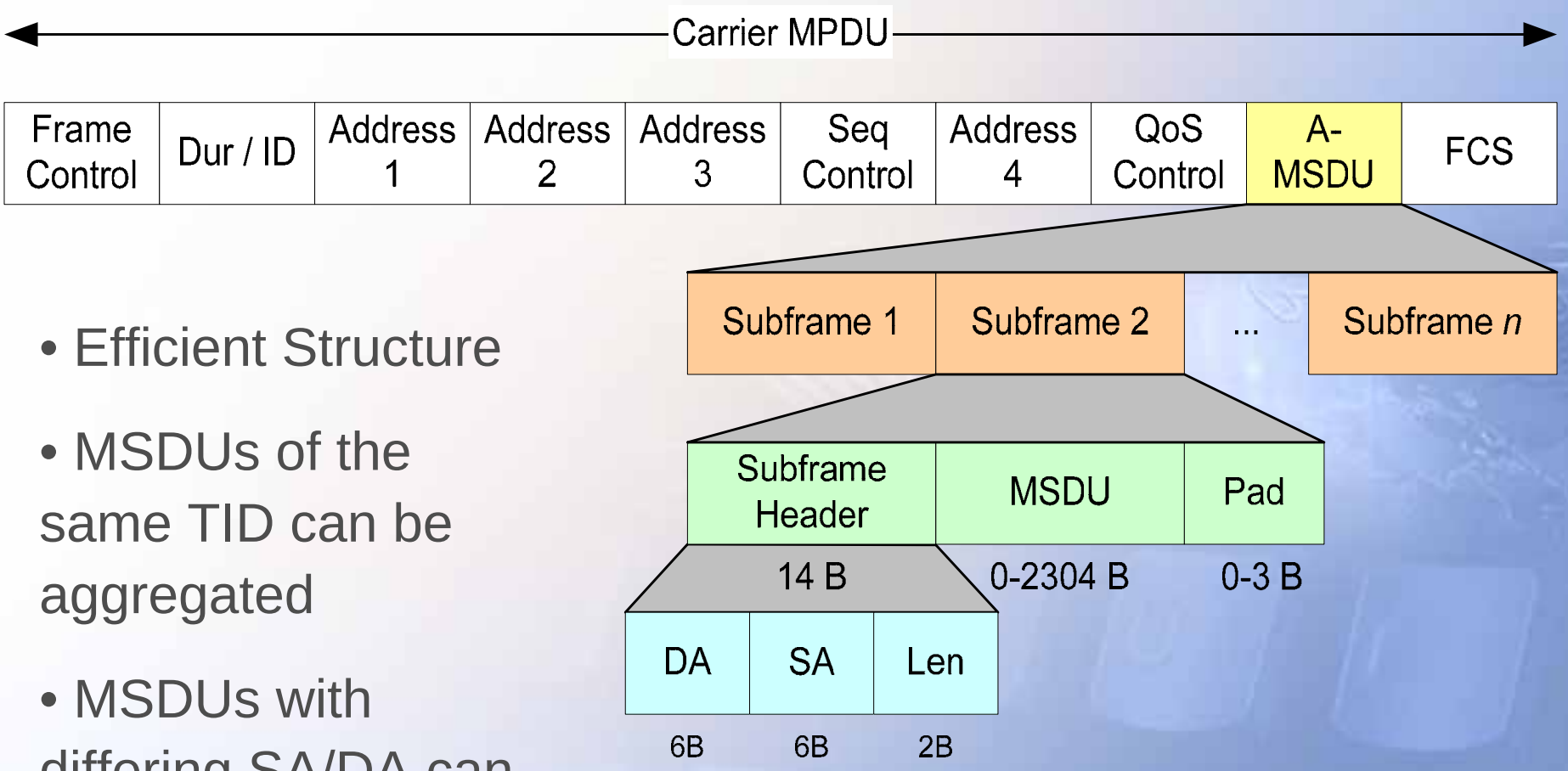
- .11a PHY, no channel error, a single STA

11n MAC Proposals

(from TGn Sync proposal)

Ref: [Sync], [WWiSE]

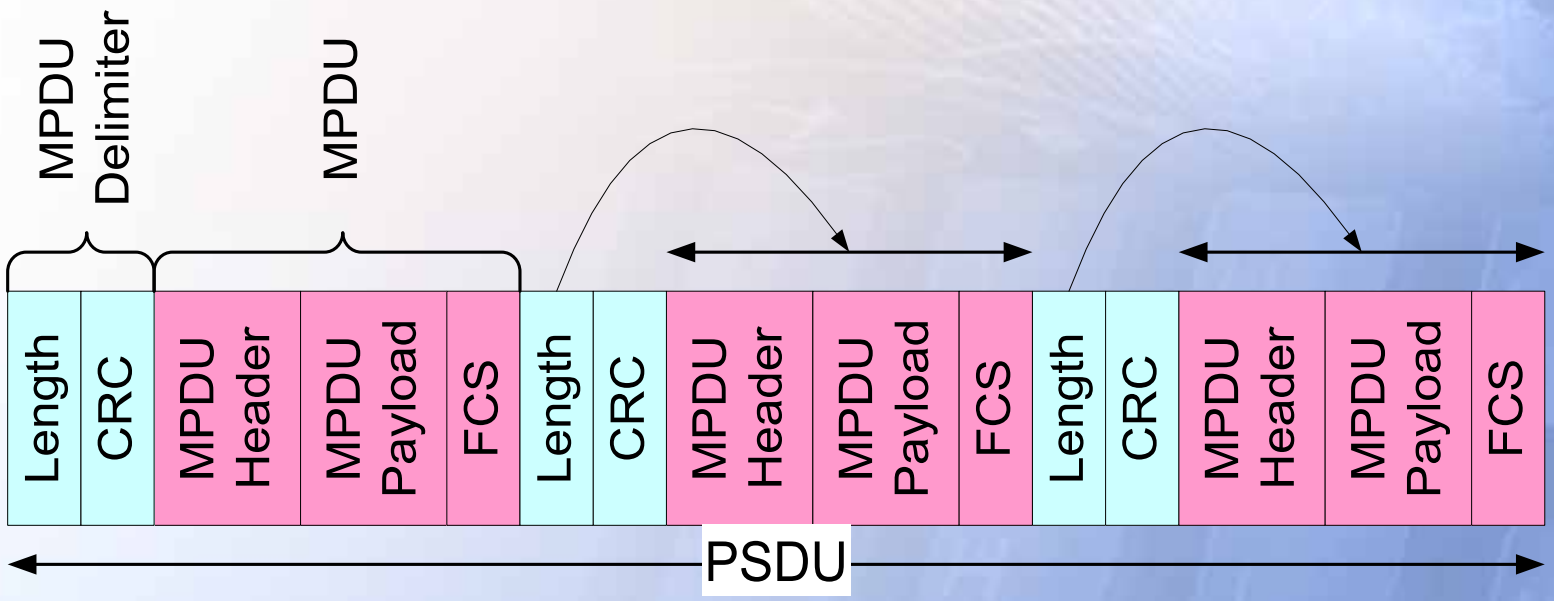
A-MSDU Aggregation



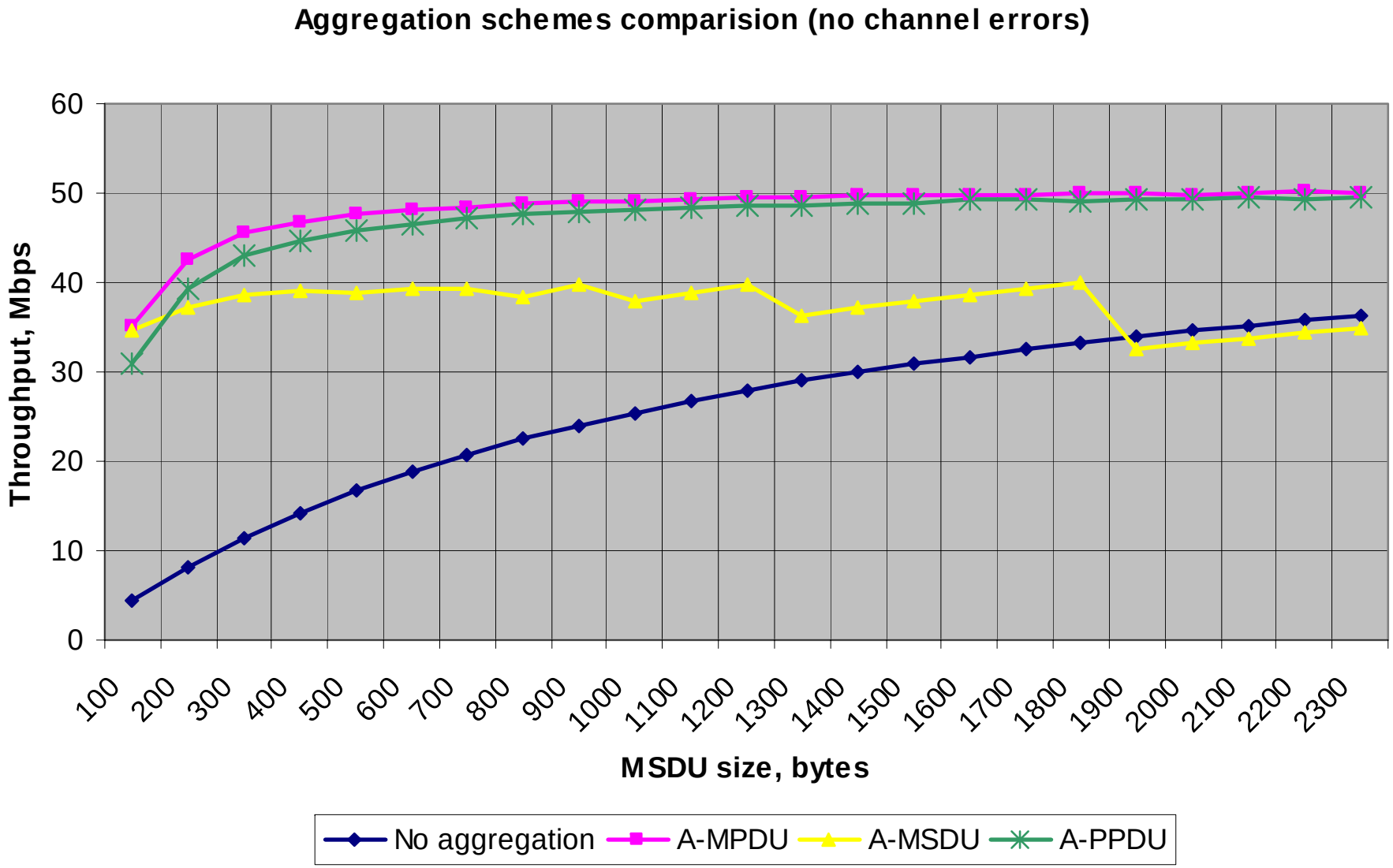
- Efficient Structure
- MSDUs of the same TID can be aggregated
- MSDUs with differing SA/DA can be aggregated

A-MPDU Aggregation

- Robust Structure
- Aggregation is a purely-MAC function
  - PHY has no knowledge of MPDU boundaries
  - Simplest MAC-PHY interface
- Control and data MPDUs can be aggregated

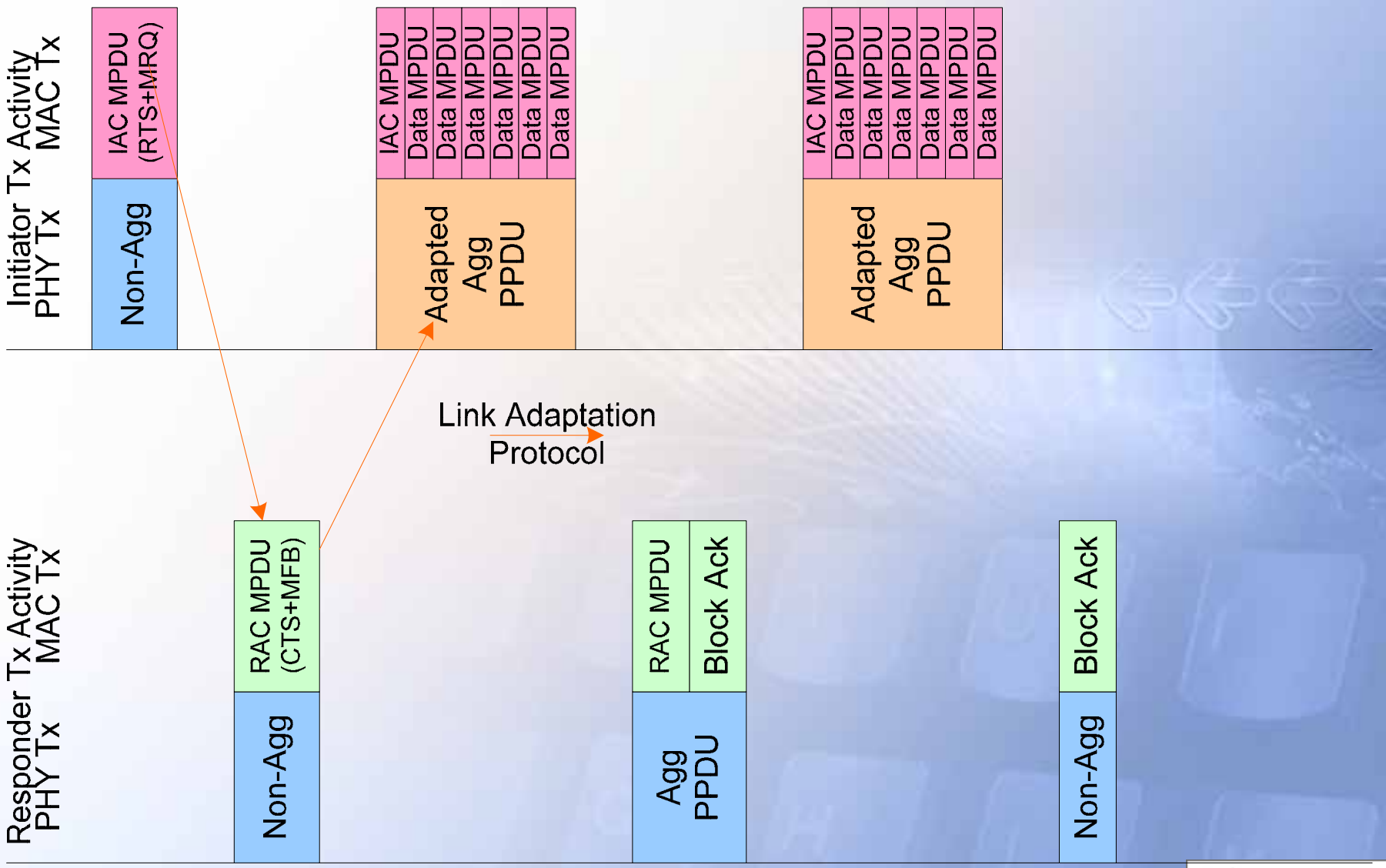


Performance Evaluation



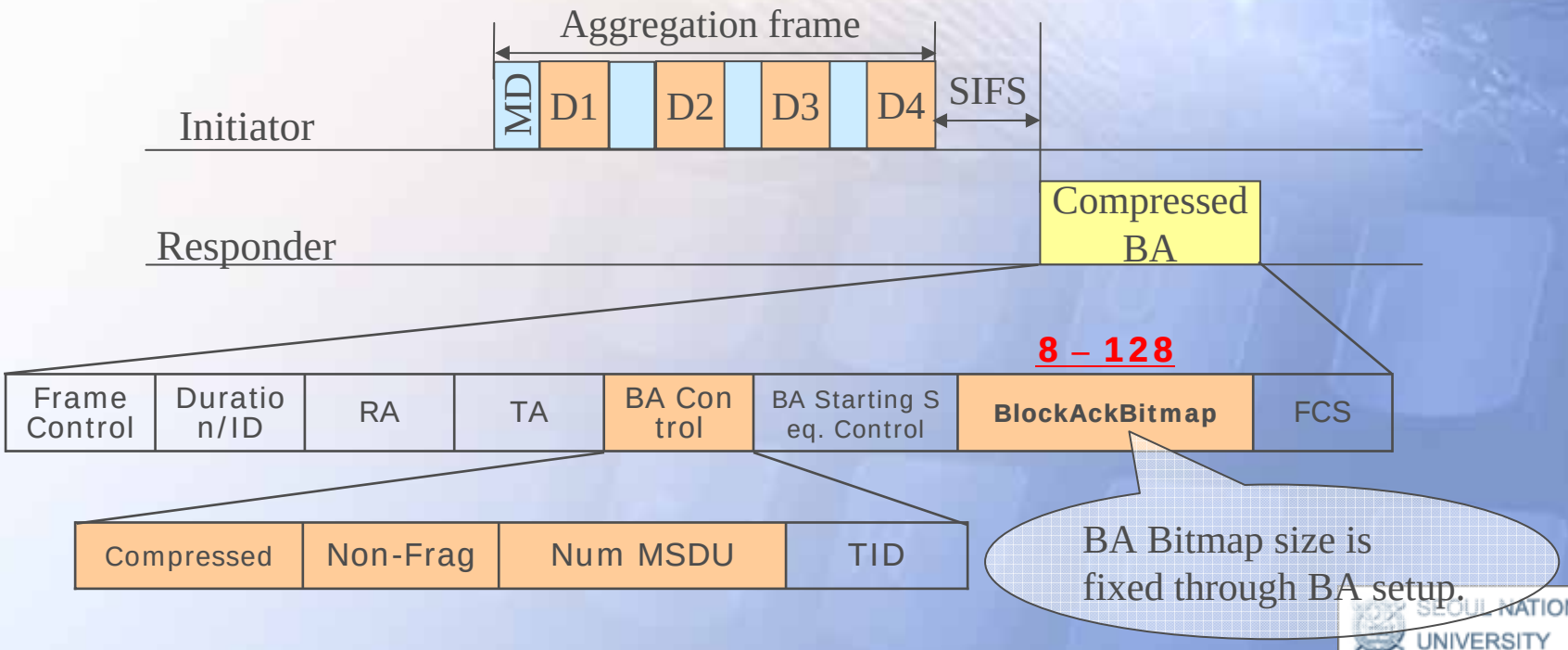
* Assuming 11a's 54Mbps tx rate

RX Assisted Link Adaptation



Enhanced Block Ack (BA)

- Compressed BA
  - Support for non-fragmented BA to reduce the bitmap size to 1 bit per MSDU
  - Truncation of the bitmap to reduce the number of MSDUs acknowledged in the bitmap



Conclusion

- IEEE 802.11 is evolving today
- Overviewed 802.11e and 11n core techniques and proposals
- 11e/n will realize true multimedia over WLAN via QoS and high-throughput supports

References

[Yang02] Yang Xiao and Jon Rosdahl, “Throughput and delay limits of IEEE 802.11,” IEEE Com. Letters, Aug. 2002.

[Tinnirello05] Ilenia Tinnirello and Sunghyun Choi, "Efficiency Analysis of Burst Transmissions with Block ACK in Contention-Based 802.11e WLANs," to appear in Proc. IEEE ICC'2005, May 2005.

[Kim04] Youngsoo Kim, Sunghyun Choi, Kyunghun Jang, and Hyosun Hwang, "Throughput Enhancement of IEEE 802.11 WLAN via Frame Aggregation," in Proc. IEEE VTC'04-Fall, Sept. 2004.

[Samsung] Kunghun Jang et al. "SAMSUNG MAC Proposal Technical Specification," IEEE 802.11-04/918r2, August 2004.

[Sync] Syed Aon Mujtaba, “TGn Sync Proposal Technical Specification,” IEEE 802.11-04/889r2, Jan. 2005.

[WWiSE] Manoneet Singh et al., “WWiSE Proposal: High throughput extension to the 802.11 Standard,” IEEE 802.11-04/886r6, Jan. 2005.