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On the Performance of IEEE 802.15.3c Millimeter-Wave WPANs: PHY and MAC

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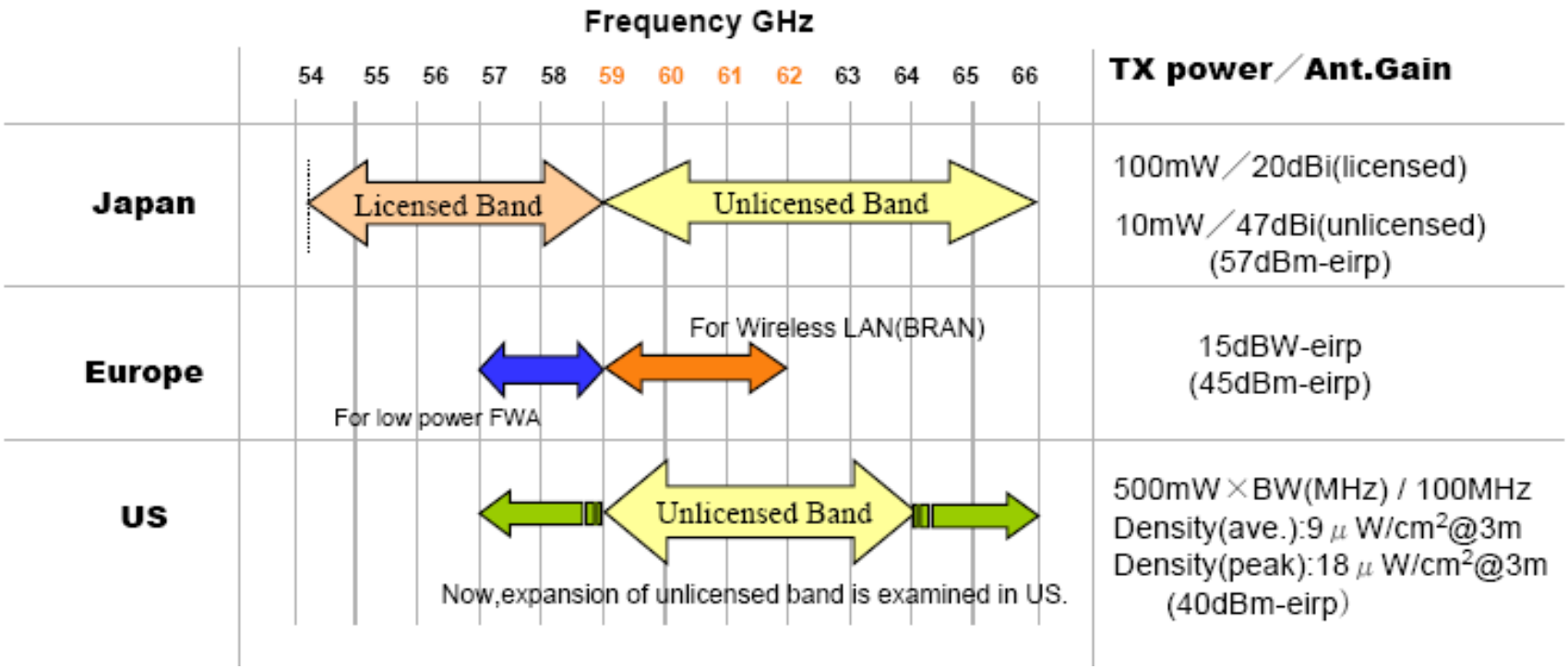
Outlines

- Introduction of Millimeter-Wave WPAN
- Overview of IEEE 802.15.3c Standard
- 60 GHz Channel Model
- Simulation Performance Analysis
- Conclusion

Introduction

- 60 GHz Frequency Band Allocation



Source: S. David Silk, Motorola

Introduction

- Standards over 60 GHz Wireless
  - IEEE 802.15.3c
  - IEEE 802.11ad
  - WirelessHD
  - WiGig
  - ECMA-387

Features:
(1) In-door (<10m)
(2) Uncompressed HDTV and high rate data transfer
(3) At least 1 Gbps throughput, 3-4 Gbps preferable

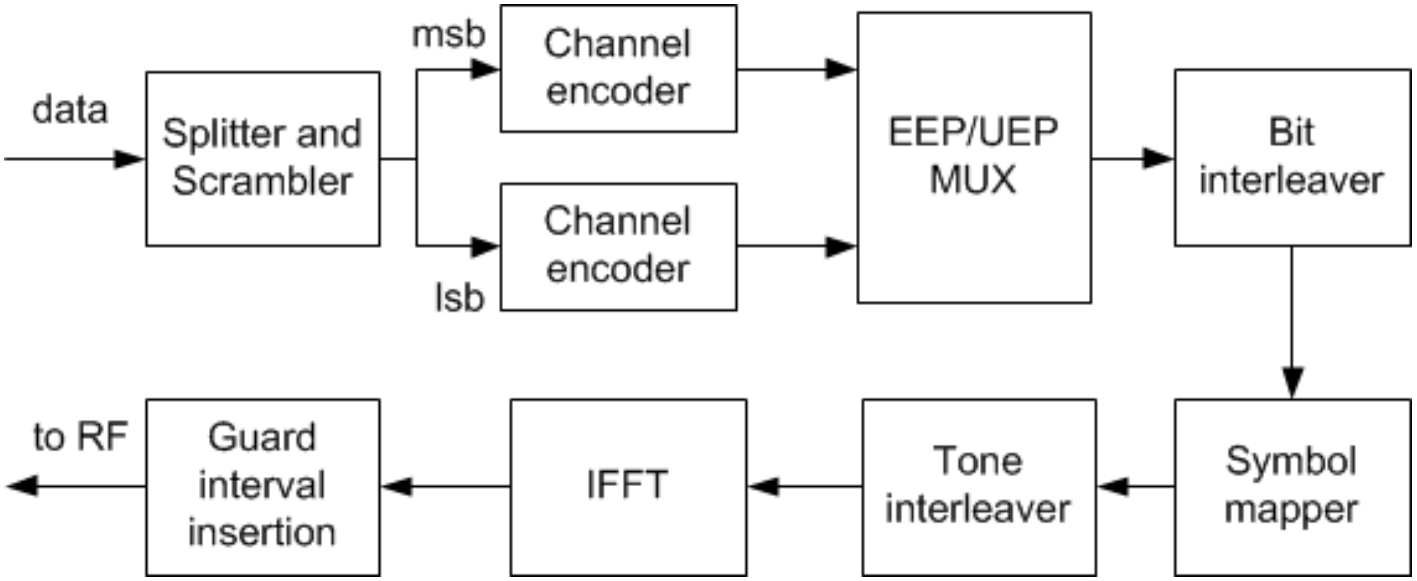
Overview of IEEE 802.15.3c

- IEEE 802.15.3c specifies three operating modes and one common mode
  - Single Carrier (SC)
    - Low power and low complexity applications
  - High Speed Interface (HSI)
    - Low latency data transferring
  - Audio/Video (AV)
    - Uncompressed high definition video/audio

MCS index	Data rate (Mb/s)	Modulation scheme	FEC rate
HSI Mode			
1	1540	QPSK	1/2
2	2310	QPSK	3/4
3	2695	QPSK	7/8
4	3080	16-QAM	1/2
5	4620	16-QAM	3/4
6	5390	16-QAM	7/8
7	5775	64-QAM	5/8
AV Mode			
0	952	QPSK	1/3
1	1904	QPSK	2/3
2	3807	16-QAM	2/3

Overview of IEEE 802.15.3c

- OFDM Based Block Diagram



The block diagram of the transmitter

Overview of IEEE 802.15.3c

- OFDM Parameters

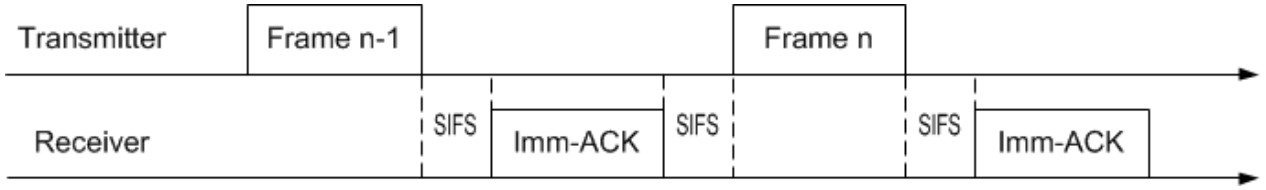
Parameter	Value	
	HSI mode	***AV mode***
Channel bandwidth (MHz)	1815	1760
Sampling frequency (MHz)	2640	2538
Number of subcarrier/FFT size	512	
Number of data subcarriers	336	
Number of pilot subcarriers	16	
Number of guard subcarriers	141	
Number of DC subcarriers	3	
Number of reserved subcarriers	16	
Guard interval length in samples	64	

Overview of IEEE 802.15.3c

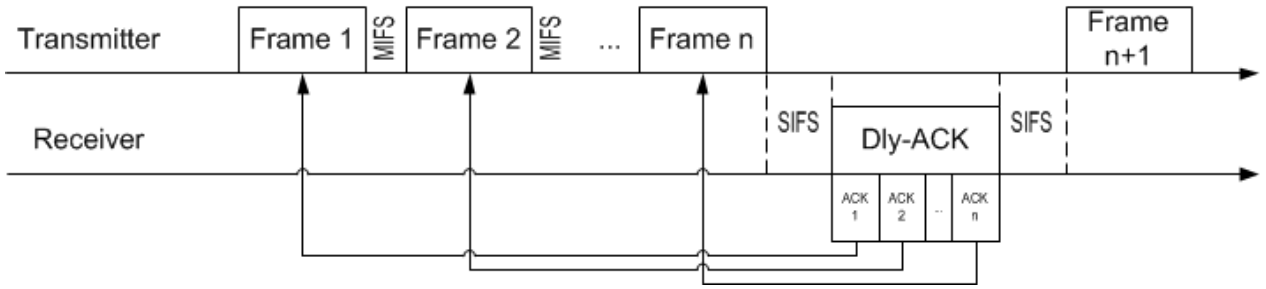
- MAC Layer Throughput
  - *Throughput = Payload/Transmission Duration*
- Source of Overhead
  - Gap Time (MIFS, SIFS, RIFS)
  - Preamble
  - Header Fields
  - ACKs

Overview of IEEE 802.15.3c

- Acknowledgment Operations (1)
  - Imm-ACK

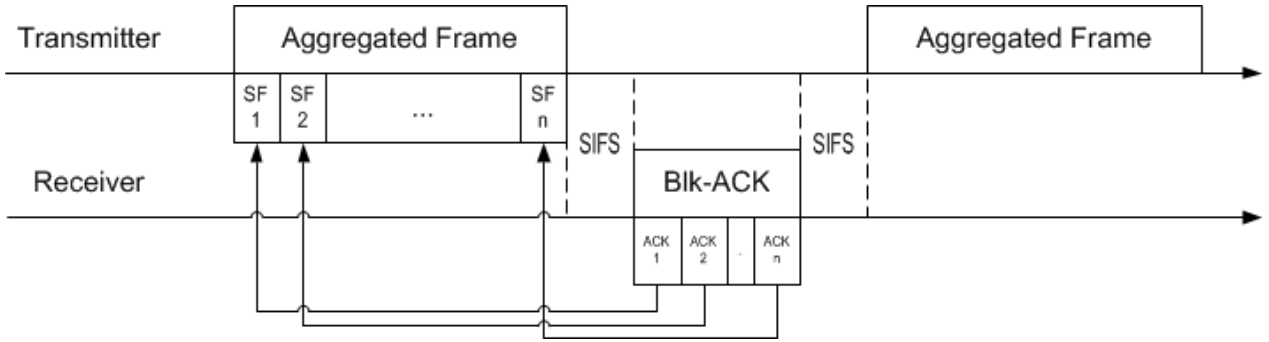


  - Dly-ACK

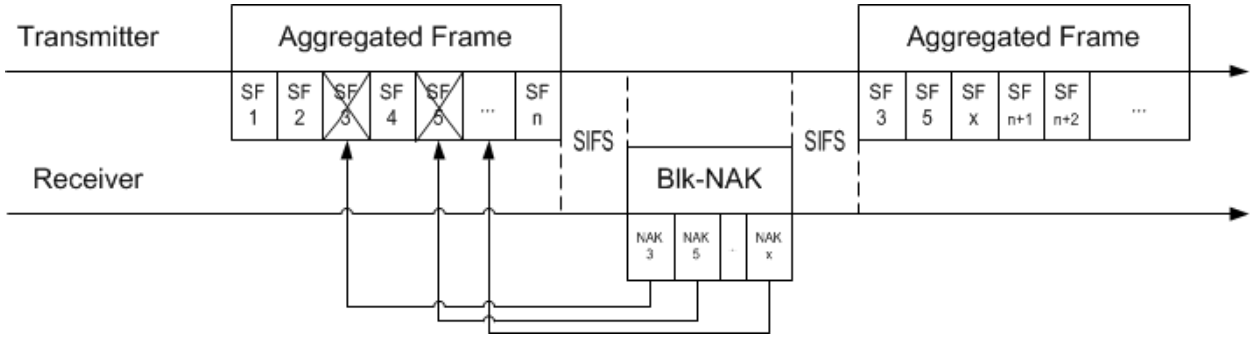


Overview of IEEE 802.15.3c

- Acknowledgment Operations (2)
  - Blk-ACK

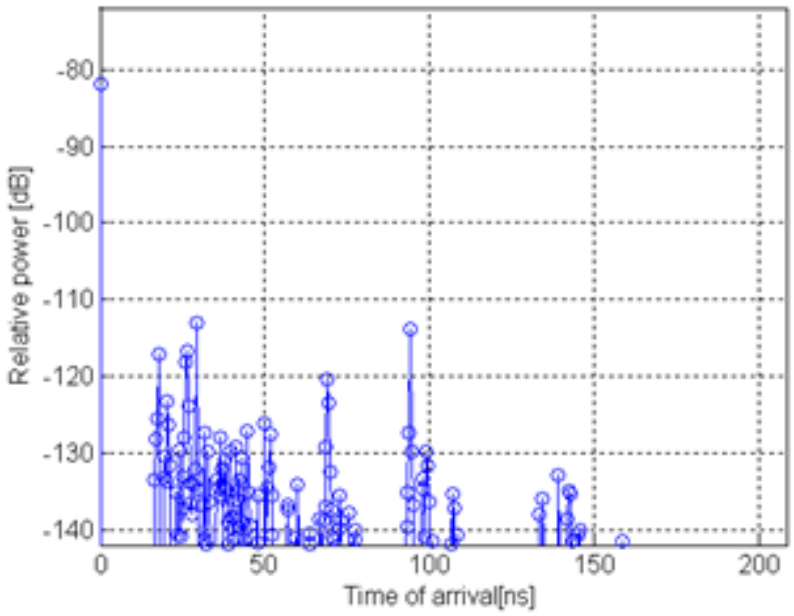


  - Blk-NAK

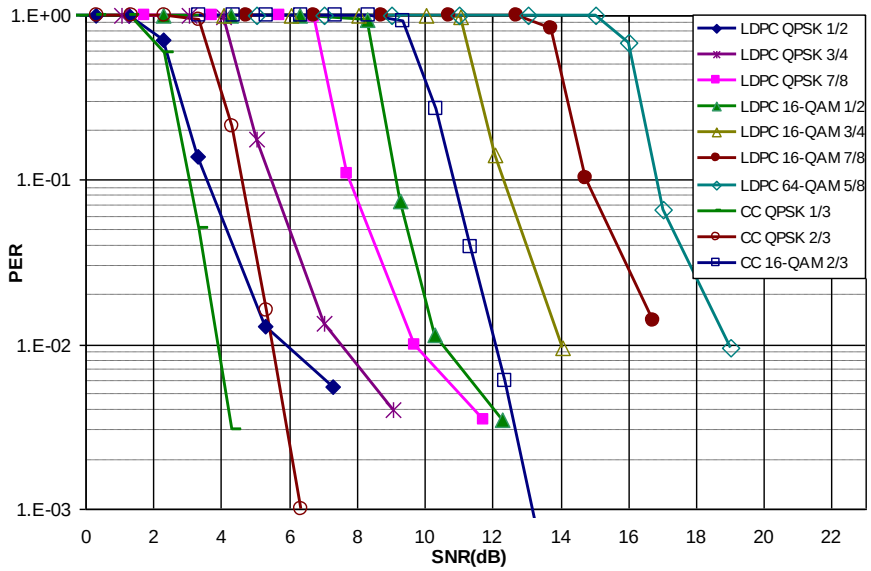


60 GHz Channel Model

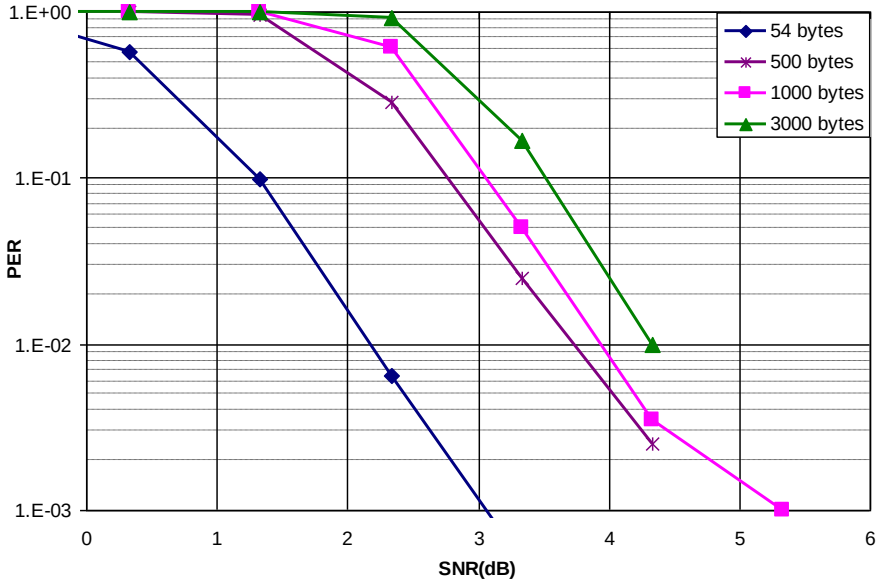
- Large Scale Fading
  - $\overline{PL}(d)[\mathrm{dB}] = PL_0 + 10 \cdot n \cdot log_{10}\left(\frac{d}{d_0}\right)$
- Small Scale Fading
  - TSV model
    - Residential
    - Office
    - Library
    - Kiosk



Performance Analysis (1)



PER performance of different modes



PER performance of different sizes

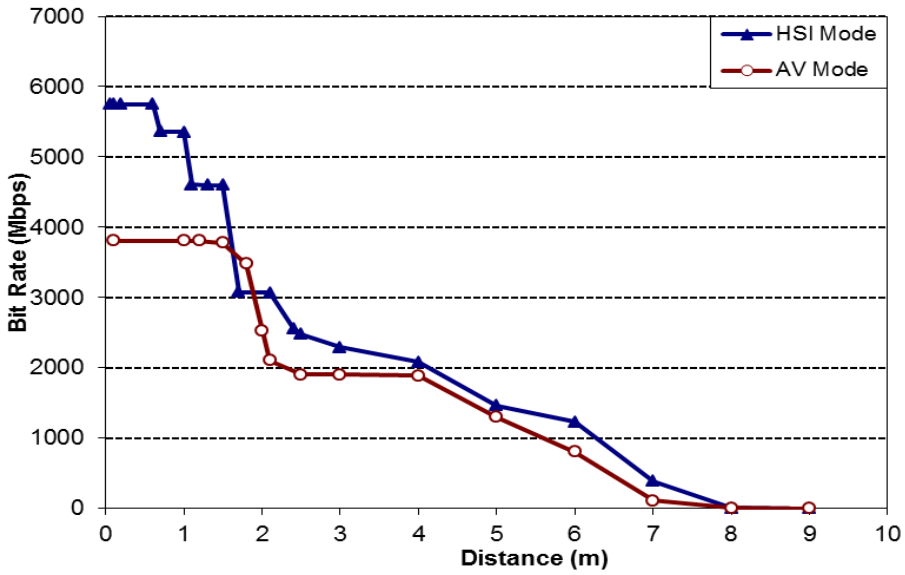
- Higher data rate requires higher SNR to maintain a certain PER
- Larger packet size results in higher SNR requirement

Performance Analysis (2)

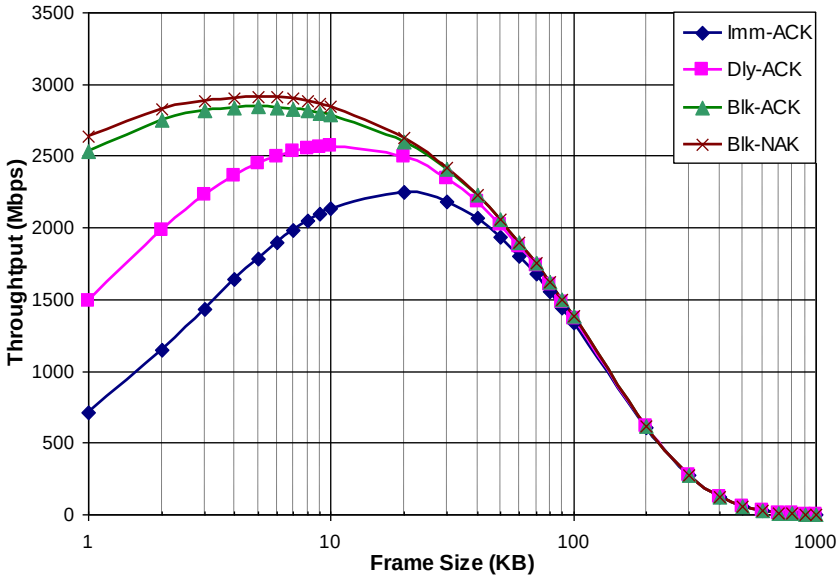
- Link Throughput
  - *Throughput = R (1- PER)*
- Operation Range
  - System Tolerant:

    7-8 m
  - High Data Rate:

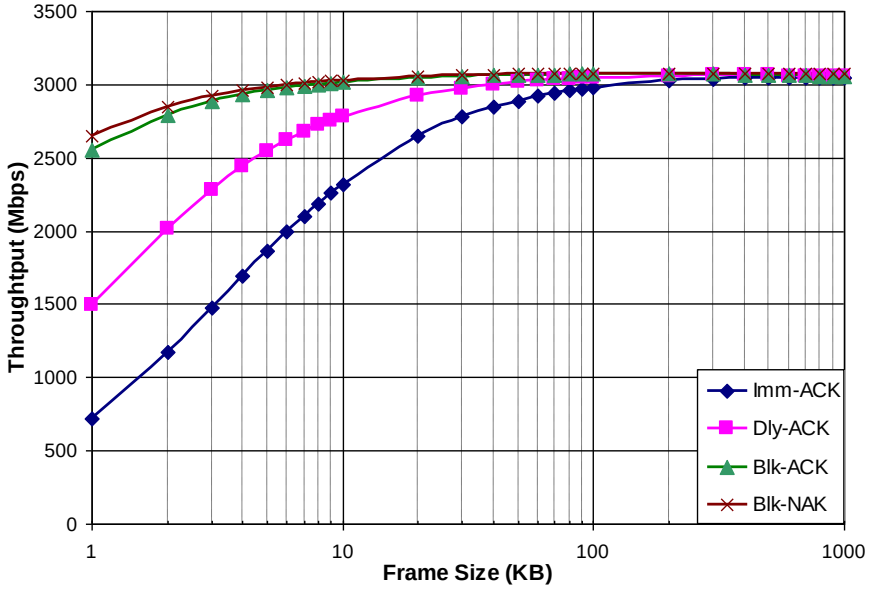
    within 1-2 m



Performance Analysis (3)



Throughput at BER=10e-6

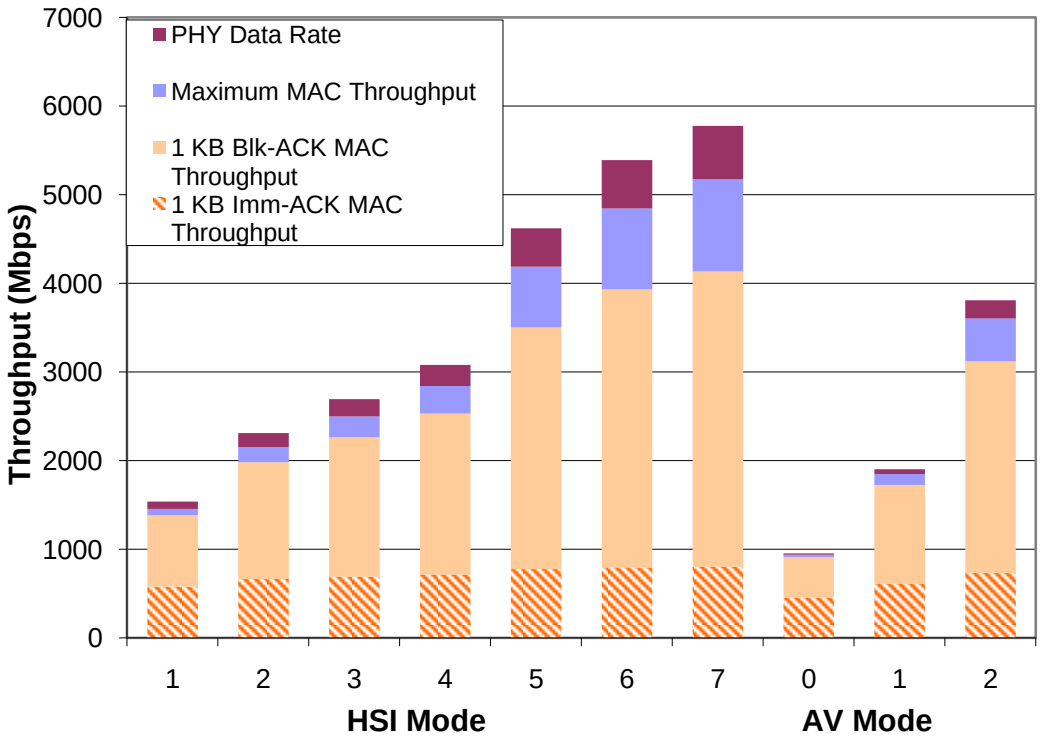


Throughput at BER=10e-9

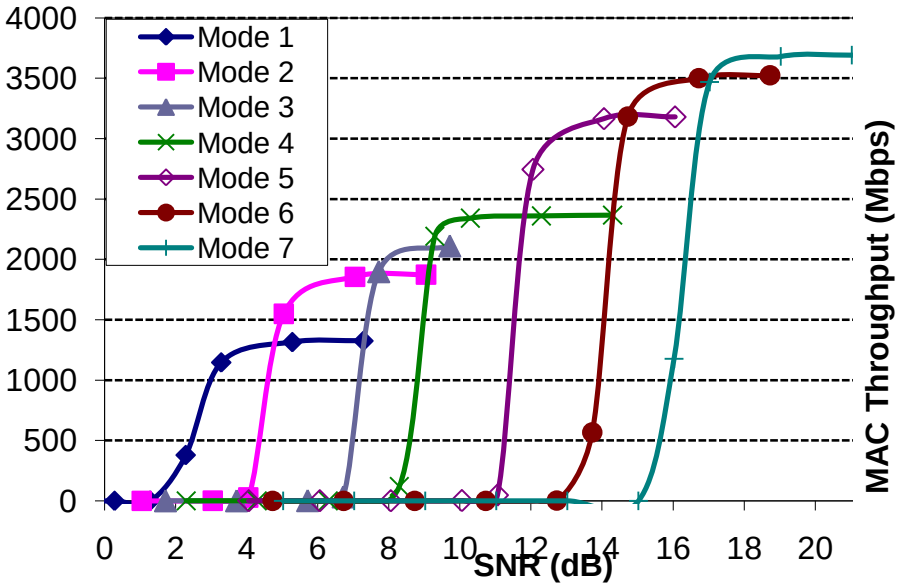
- Blk-ACK increases the MAC efficiency by up to 30%
- When BER is high, the MAC throughput increases up to a certain point with the increase of the frame size, then decreases
- When BER is low, the MAC throughput increases

Performance Analysis (4)

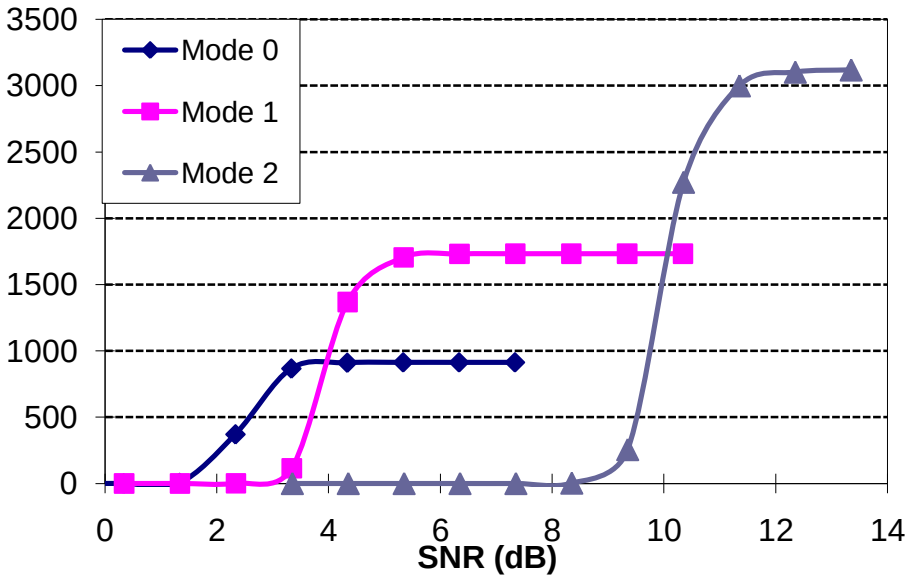
- Achievable MAC Throughput
  - Imm-ACK throughput does not significantly change
  - Blk-ACK throughput varies depending on the data rate



Performance Analysis (5)



HSI link throughput for 1KB Blk-ACK



AV link throughput for 1KB Blk-ACK

- The MAC efficiency with Blk-ACK for 1KB payload varies from 72% to 96%
- The link throughput decrease due to the MAC layer overhead

Conclusion

- A detailed performance evaluation of the IEEE 802.15.3c standard over 60 GHz channel
- The guaranteed high data rate transmission range is within 2 meters
- Frame aggregation with Blk-ACK could increase the MAC throughput by 30%
- A 10-30 KB frame size could achieve the maximum MAC throughput under 10^{-6} BER, but may result in increased retransmission and delay; However, smaller frame size results in low MAC throughput efficiency

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Thank you!