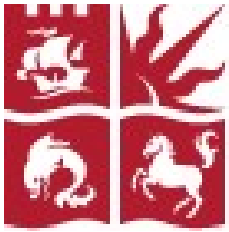
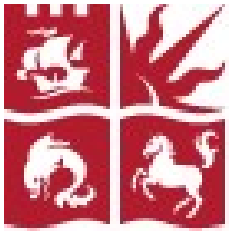


EENGM4221: Broadband Wireless Communications

Lecture 18: Bluetooth Frame types, MAC Efficiency and Link Adaptation

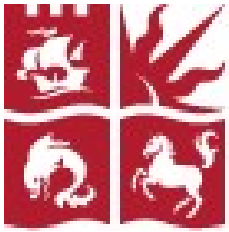
Dr Simon Armour

Multislot Packets (1)

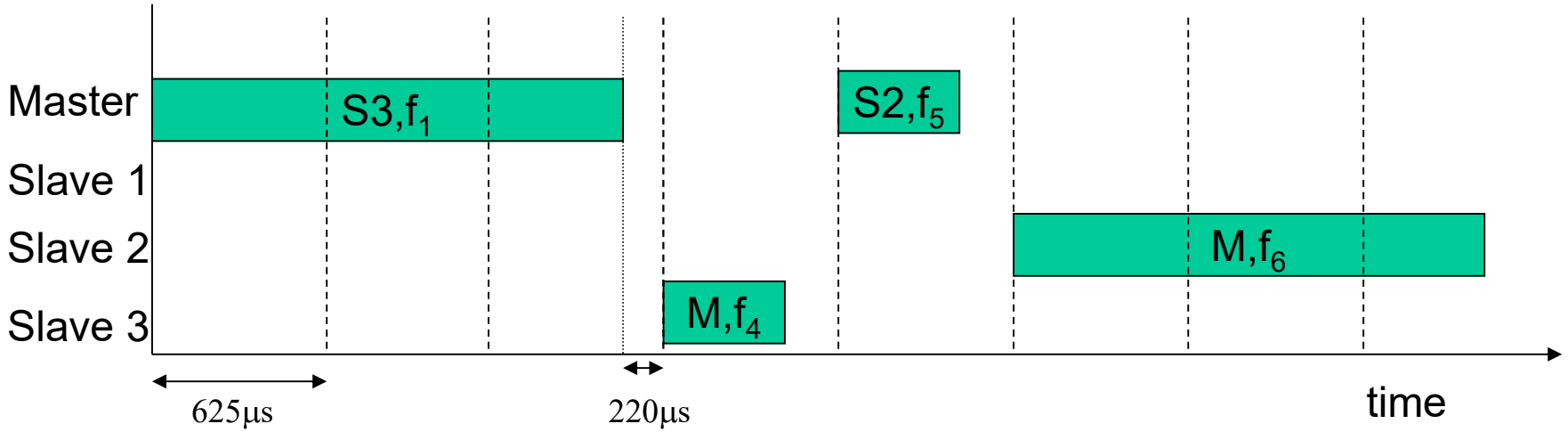


- Bluetooth allows packets to occupy either 1, 3 or 5 time slots
- More timeslots allow for a larger packet payload
- Since the overheads associated with the packet (radio turnaround, access code, header) are fixed in duration, larger payloads are more efficient
- 3 and 5 slot packets are only possible for ACL links, not SCO
- Only odd numbers are allowed so that the even/odd slot Master/Slave mapping is maintained
- Use of multislot packets may be symmetric or asymmetric

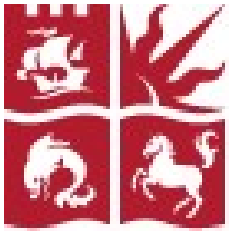
Multislot Packets (2)



- If a multislot packet is transmitted, the hop frequency is fixed for the duration of the packet. Subsequently, the piconet hops to the next frequency expected if multislotting were not allowed
  - As a result, only 1 silent period is required at the end of the packet rather than one per slot



MAC Efficiency (1)



- The Bluetooth MAC adds significant overhead
- The efficiency may be evaluated according to:

$$\eta_{MAC} = \frac{T_{Payload}}{T_{Payload} + T_{AccessCode} + T_{Header} + T_{Silent}}$$

- Since the Access Code, Header, and Silent Period are all of fixed length and the symbol rate is 1Mbaud

$$\eta_{MAC} = \frac{Payload\_Size}{Payload\_Size + 72 + 54 + 220}$$

- Which demonstrates the benefit of a larger payload

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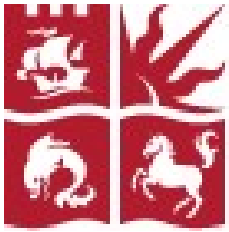
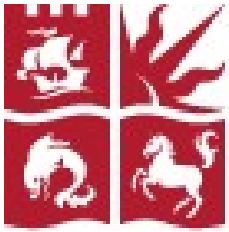
Packet Types (1)



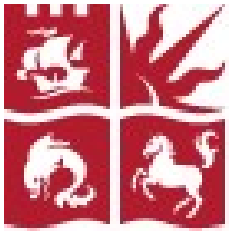
- Bluetooth allows various packet types according to combinations of packet size coding strategy and slot length
- Data Medium (DM) are ACL packets with 2/3 coding of the payload
- Data High (DH) packets are ACL packets with uncoded payloads
- Either may be 1, 3 or 5 slots long and hence termed DM1, DM3, DM5, DH1, DH3 or DH5
- A 1 slot ACL link with no FEC or ARQ is also allowed and termed AUX1

Packet Types (2)



- SCO links may not use multiple slots. Three SCO packet types are defined according to the number of bytes per packet:
- 10 bytes with 1/3 rate FEC (HV1)
- 20 bytes with 2/3 rate FEC (HV2)
- 30 bytes with no FEC (HV3)

Data Rates



Packet Type	Symmetric Rate (kbps)	Asymmetric Data Rate (kbps)	
DM1	108.8	X	X
DH1	172.8	X	X
DM3	256	384	54.4
DH3	384	576	86.4
DM5	286.7	477.8	36.3
DH5	432.6	721	57.6
AUX1	172.8	X	X
HV1	64	X	X
HV2	128	X	X
HV3	192	X	X

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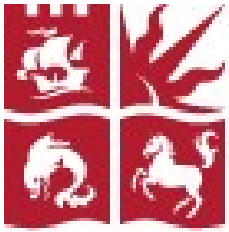
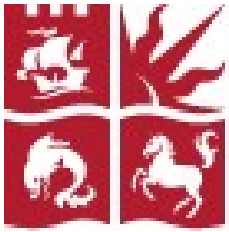
MAC Efficiency Revisited



- The MAC Efficiency equations demonstrated the advantage of a larger payload
- This can be reconsidered in the context of the allowed packet types
- The payload is limited to a maximum of 2745 bits in a DH5 packet which equates to 89% efficiency
  - This is represents quite an efficient MAC
- The smallest payload for which the packet is ‘full’ is for the case of a HV1 packet in which case the number of bits is 80. In this case the MAC efficiency is 19%.
- In theory, the payload may be zero is which case efficiency is not so high…
- In practice there will be some loss since packets of any type will not always be of maximal length
- The overall MAC efficiency for a period of time will be an average of all the packet types and sizes transmitted during that time.

Link Adaptation (1)



- Link Adaptation was not considered in the design of Bluetooth
- However, that does not make it impossible
- It can be seen that different packet types achieve different throughput
- It is intuitive that packets with different FEC rates will have different reliability
  - Different BER and hence different PER
- Likewise, different size packets will have different error probability
  - Fixed BER but variable number of bits results in variable PER

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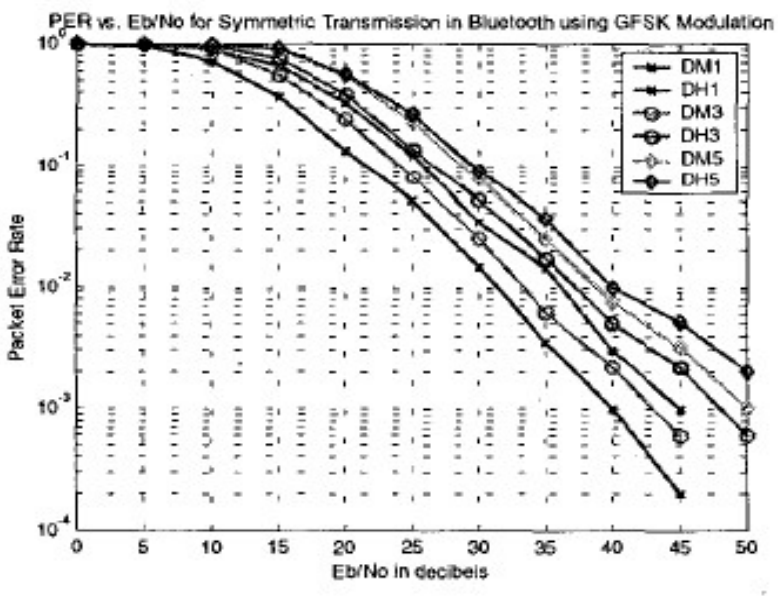
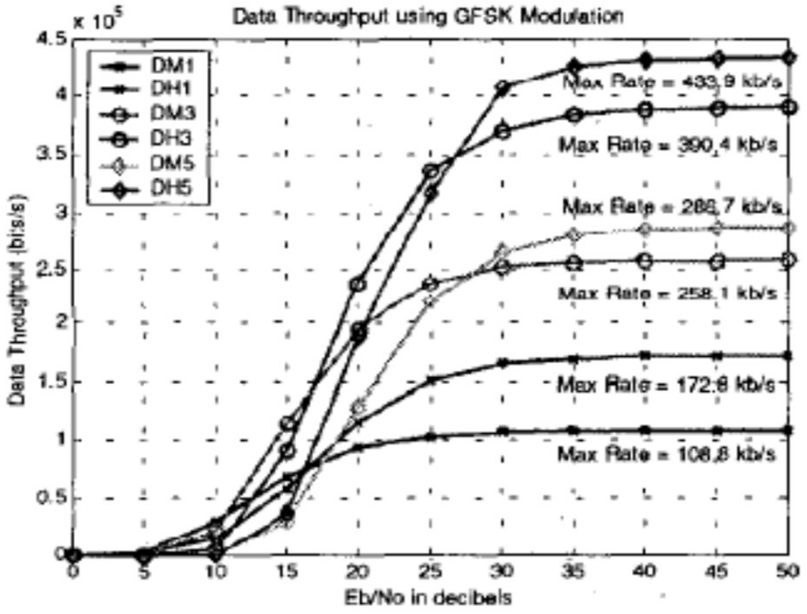
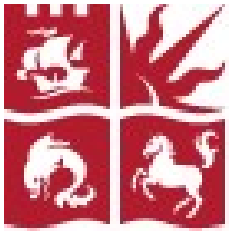
Link Adaptation (2)

- The packet type may be changed in Bluetooth for Link Adaptation purposes as illustrated here for ACL
- Something similar (but more limited) can be done for SCO



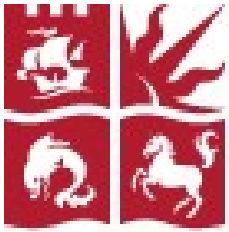


Bluetooth Evolution



- Bluetooth has undergone a number of version changes and revisions. New features include:
  - AFH (v1.2)
  - Higher order modulation: 8PSK (v2.0)
  - Simplified device pairing (v2.1)
  - Bonding with WiFi (v3.0 + HS)
  - Low Energy Consumption (v4.0 LE)
  - LTE Coexistence (v4.1)
  - IoT Features (v4.2)
  - Further enhancements to Low Energy in v5

Review of Lecture 18



- We explored the strategy of multislot packets to increase throughput
- We considered MAC efficiency
- We reviewed the different packet types allowed and the throughputs they could achieve
- We outlined limited options for Link Adaptation
- We reviewed evolutions of the standard

Ref: