EEENGM4221:
Broadband Wireless Communications

Lecture 15: 802.11 Limitations and Evolutions

Dr Simon Armour

QoS in 802.11

- QoS provision in 802.11 can be summarised as…

…non-existent

- The 802.11 MAC treats all incoming MSDUs identically and deals with them on a first come first served basis
  - No provision for priority
- All nodes compete for access to the channel
  - No consideration is given to the QoS needs of any particular service
  - The delay between any node's successful accesses to the channel is completely undefined and uncontrolled
    - This affects delay and data rate

Ref:

Infrastructure and Ad-Hoc Modes

- Most 802.11 BSSs operate in Infrastructure mode
- Infrastructure mode dictates that all traffic be sent via an Access Point
  - Hence in Infrastructure mode the network has a star topology
- The alternative is ad-hoc mode where nodes may transmit data directly to one another

The DCF-Infrastructure Dichotomy

- The vast majority (estimated 9/10) of 802.11 BSSs are deployed in Infrastructure mode whilst using a DCF MAC protocol
- This is dumb – really dumb!
- We have seen that the DCF has been designed with great effort to make it work in a distributed fashion
- What is the point of this if most deployments are Infrastructured?
- Why not allow central scheduling to improve QoS
  - (Answer: Because PCF is flawed)
- If we are going to use a distributed MAC protocol, why not allow a Mesh topology?

Ref:

802.11 Efficiency (1)

- The efficiency of the 802.11 MAC in DCF mode is impaired by the overheads due to MAC and PHY Headers, CRCs, IFSs, ACKs, CW, optional RTS/CTS, etc
- The efficiency may be quantified in the absence of RTS/CTS as:

$$\eta_{MAC} = \frac{T_{MSDU}}{T_{DIFS} + T_{CW} + T_{PHead} + T_{MHead} + T_{MSDU} + T_{CRC} + T_{SIFS} + T_{ACK}}$$

802.11 Efficiency (2)

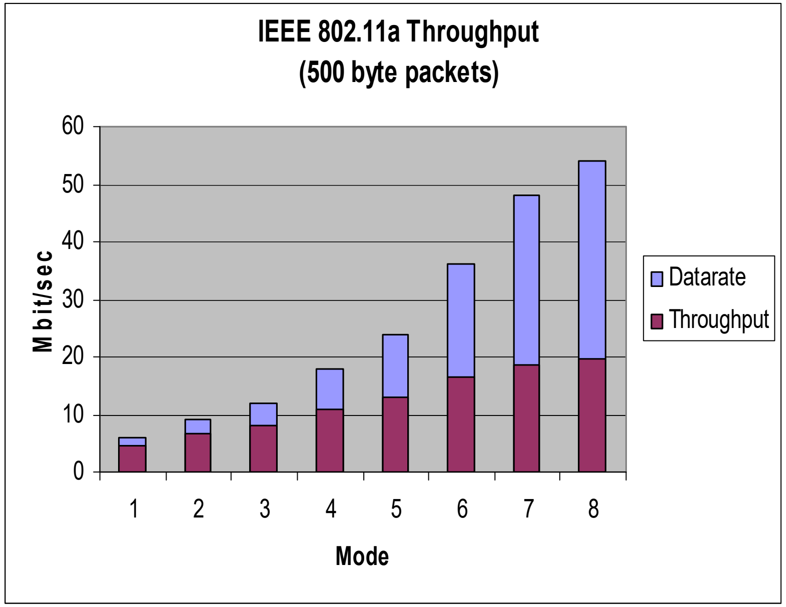
- With RTS/CTS (and the associated extra SIFSs) this becomes:

$$\eta_{MAC} = \frac{T_{MSDU}}{T_{DIFS} + T_{CW} + T_{RTS} + 3T_{SIFS} + T_{CTS} + T_{PHead} + T_{MHead} + T_{MSDU} + T_{CRC} + T_{ACK}}$$

- It is not easy to quantify this efficiency since almost all of the lengths depend upon the PHY parameters
  - T_{SIFS}, T_{DIFS} and T_{PHead} vary between different PHY specifications
  - T_{CW} is a random variable
  - All others are dependent upon the data rate of the PHY
    - Each PHY spec supports multiple data rates!

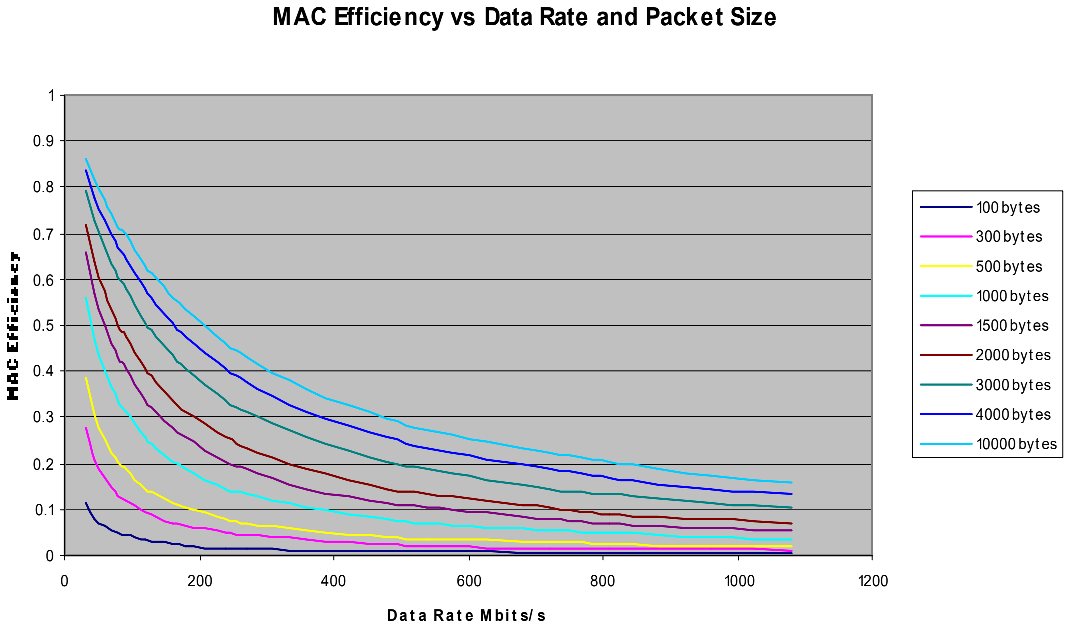
802.11a/g MAC Efficiency

- Given knowledge of the length (in seconds) of some of the terms in the MAC efficiency equations and knowledge of the size (in bits) of some of the others in combination with the PHY rate, it is possible to evaluate the MAC efficiency of 802.11a and g as a function of packet size and PHY mode
  - 500 bytes is a commonly accepted average packet size for Ethernet



The Compression Effect

- The efficiency results show clear diminishing returns – 'compression effect'
- This is exacerbated if:
  - the packets are shorter
  - The PHY rate increases
- This poses a problem for the future of 802.11
- These results are without RTS/CTS
- Things get even worse when RTS/CTS is added



- MAC efficiency limits throughput to around 100Mbits/s no matter how fast the PHY is!

802.11 Evolution – 11e

- 802.11e attempted to improve the MAC protocol to add QoS support
  - Introduced the idea of ‘traffic classes’
  - Treated each traffic class as a virtual node within one device and applied different parameters to each
    - Allowed bursts of packets
    - Changed DIFS
    - Changed the CW range
  - Was constrained by backwards compatibility requirements

Ref:

802.11 Evolution – 11n (1)

- 802.11n made key changes to the preceding PHY specs by adding:
  - Multiple Input Multiple Output (MIMO) capabilities – use of multiple antennas at transmitter and receiver to enable space time coding and spatial multiplexing (as covered in EENGM2510 AMRT)
    - 4 spatial streams in 802.11n approximately quadruple the data rate (AND the bandwidth efficiency)

802.11 Evolution – 11n (2)

- Channel bonding – combine 2 20MHz channels and eliminate the gap between them to approximately double the data rate (NOT the bandwidth efficiency)
    - Consider how this interacts with the compression effect…
- Adding more sophisticated error control (turbo codes and LDPC codes) to improve the bandwidth efficiency - SNR requirement tradeoff)

- 802.11n achieves data rates up to 130Mbits/s in its basic form and 600Mbits/s with all its features turned on

Ref:

802.11 Evolution – 11ac and ax

- 802.11ac continues down the path of 11n by adding more antennas, more spatial streams (8) and larger channel bandwidths (if there are enough available).
  - These features combine to achieve a nominal 7Gbps
    - This is unlikely in practice
    - The bandwidth efficiency IS improving but not nearly as much as the claimed peak rate would imply
- 802.11ax puts more emphasis on channel management than link throughput with a view to deploying access points more densely to achieve better traffic density

Ref:

802.11 Evolution – 11ad and ay

- 802.11ad shifts attention to the use of mmWave bands (e.g. 60GHz ISM band)
- This facilitates access to yet more bandwidth but requires significant beamforming to overcome the much higher link losses at mmWave
- The change of frequency eliminates the backward compatibility issue and so a MAC redesign is a more viable option and is actually needed in order to facilitate the beamforming
- ay is yet another evolutionary step but this time building upon ad at mmWave

Go faster

- 11n and ac are examples of a persistent ‘go faster’ mentality in .11/WiFi
- However, reflection on the MAC efficiency analysis shows us that with the legacy MAC we get diminishing returns on PHY layer rates due to MAC inefficiencies
- For some time these standards seemed to be going down something of dead end road with the MAC being neglected but more holistic thinking (eg. in ad and ax) seem to be addressing this at last
- With only the legacy MAC, these ‘go faster’ PHYs only really seem to achieve a big number to market product with rather than a good technological solution

Review of Lecture 15

- We reviewed some of the limitations of 802.11
  - Basically, Simon had a real good moan about it!
  - QoS provision is poor!
  - Distributed Star Topologies make no sense!
  - MAC efficiency scales really badly with PHY rate…
  - 802.11 seems obsessed with ‘go faster’
- But despite these problems, WiFi is a success
  - Some versions such as e, ad, ax etc seem to see a bigger picture

Ref: