Mobile and Sensor Systems

Lecture 3: Wireless LAN and Bluetooth & Ad Hoc Routing

Dr. Cecilia Mascolo

UNIVERSITY OF CAMBRIDGE

In this Lecture

- We will describe
- The Wireless LAN standard
- The Bluetooth standard
- We will introduce the concept of ad hoc networking and ad hoc network routing

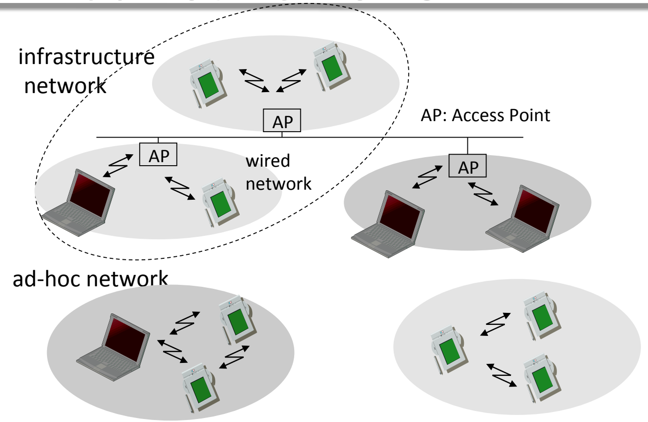
UNIVERSITY OF CAMBRIDGE

The Wireless LAN Standard

- The Mobile technology standard for LAN is called 802… and defined by the IEEE
- 802.3 is Ethernet
- Various examples of it exist:
  - 802.11 is the wireless LAN standard
  - 802.15 is wireless PAN (personal area network)
    - Zigbee is 802.15.4
    - Bluetooth is 802.15.1
  - 802.16 is WIMAX
  - 802.11 uses 2.4 and 5 GHz frequency bands (802.11g operates at 54Mbit/s with 22Mbit/s in average)
- Wireless LAN operates in 2 modes: infrastructured and ad hoc

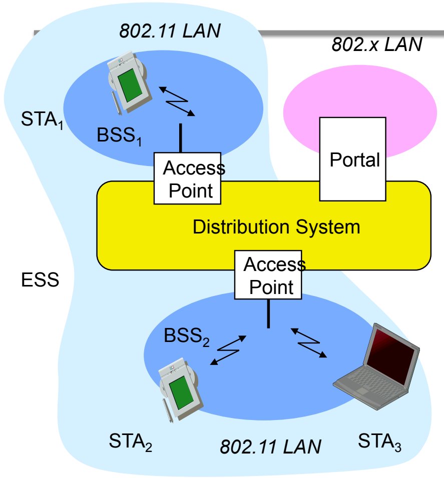
UNIVERSITY OF CAMBRIDGE

Comparison: infrastructure vs. ad-hoc networks



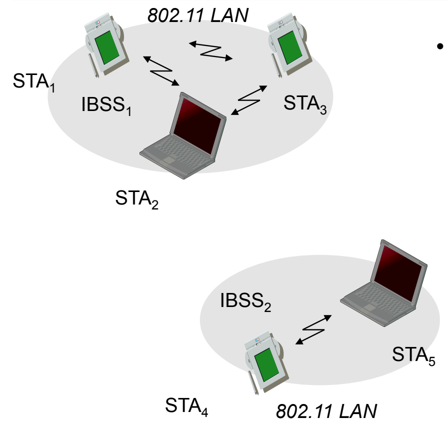
UNIVERSITY OF CAMBRIDGE

802.11 - Architecture of an infrastructure network



- Station (STA)
  - terminal with access mechanisms to the wireless medium & radio contact to AP
- Basic Service Set (BSS)
  - group of stations using the same radio frequency
- Access Point
  - station integrated into the wireless LAN and the distribution system
- Portal
  - bridge to other (wired) networks
- Distribution System
  - interconnection network to form one logical network (Extended Service Set with id ESSID) based on several BSS

802.11 - Architecture of an ad-hoc network

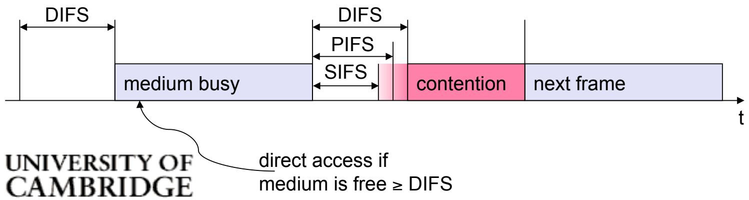


- Direct communication within a limited range
  - Station (STA): terminal with access mechanisms to the wireless medium
  - Independent Basic Service Set (IBSS): group of stations using the same radio frequency

UNIVERSITY OF CAMBRIDGE

802.11 - MAC layer (recap)

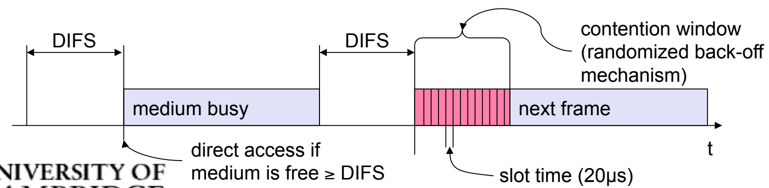
- Priorities
  - defined through different inter frame spaces
  - no guaranteed, hard priorities
  - SIFS (Short Inter Frame Spacing)
    - highest priority, for ACK, CTS, polling response
  - PIFS (PCF IFS)
    - medium priority, for time-bounded service using PCF
  - DIFS (DCF, Distributed Coordination Function IFS)
    - lowest priority, for asynchronous data service



UNIVERSITY OF CAMBRIDGE

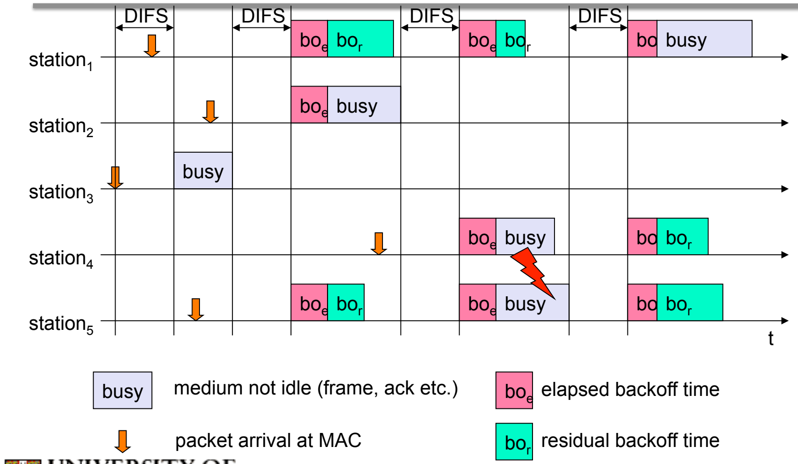
802.11 – CSMA/CA access method I

- station ready to send starts sensing the medium
- if the medium is free for the duration of an Inter-Frame Space (IFS), the station can start sending (IFS depends on service type)
- if the medium is busy, the station has to wait for a free IFS, then the station must additionally wait a random back-off time (collision avoidance, multiple of slot-time)
- if another station occupies the medium during the back-off time of the station, the back-off timer stops (fairness)



UNIVERSITY OF CAMBRIDGE

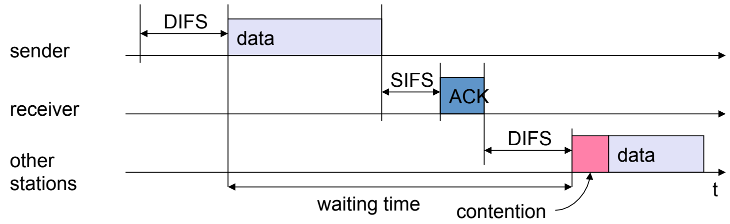
802.11 – competing stations



UNIVERSITY OF CAMBRIDGE

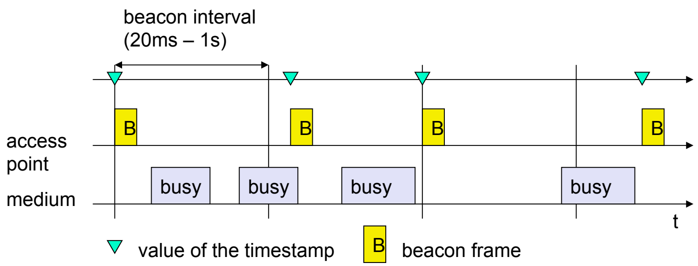
802.11 – Unicast/Ack

- Sending unicast packets
  - station has to wait for DIFS before sending data
  - receivers acknowledge at once (after waiting for SIFS) if the packet was received correctly (CRC)
  - automatic retransmission of data packets in case of transmission errors



UNIVERSITY OF CAMBRIDGE

Synchronization using a Beacon (infrastructure)

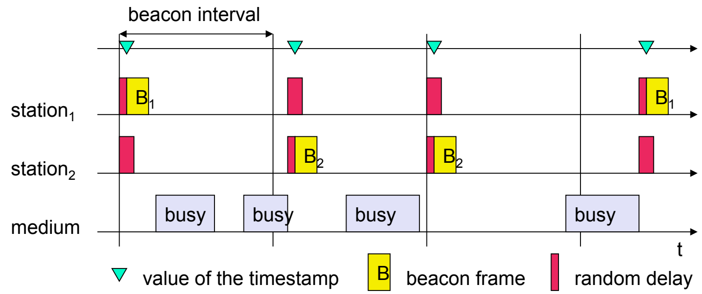


•Nodes need to keep a tight synchronized clock with the access point: this is useful for power management and coordination of frequency hopping or contention slots.

•Beacons are sent semi-periodically [ei when the medium is not busy]

UNIVERSITY OF CAMBRIDGE

Synchronization using a Beacon (ad-hoc)



•In ad hoc mode each station transmits a beacon after the beacon interval [semi periodic again]

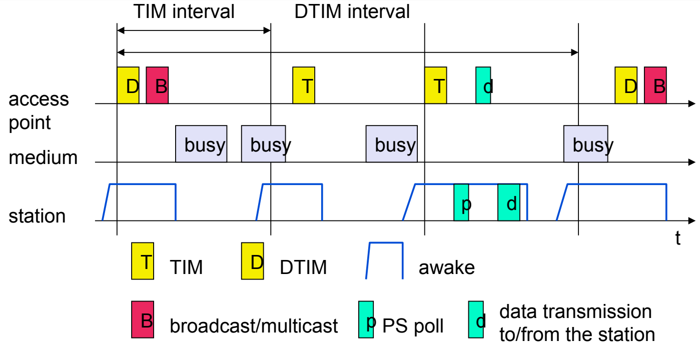
•Random backoffs are applied to beacons too: all station adjust clock to beacons received and suppress their beacon for the beacon interval

UNIVERSITY OF CAMBRIDGE

Power Management

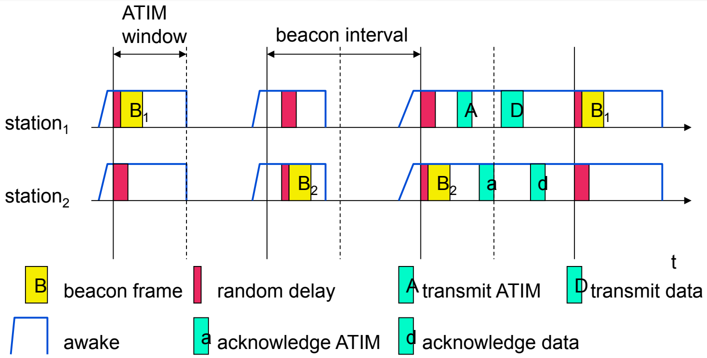
- Staying awake and transmitting is expensive for mobile stations as listening to the radio interface consumes power.
- Strategies have been devised to minimize awake times of mobile terminals while guaranteeing communication.

Power saving with wake-up patterns (infrastructure)



TIM: list of stations for which there will be data in the slot
DTIM Interval indicates the delivery traffic indication map: for broadcast and multicast frames. It's a multiple of TIM

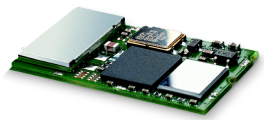
Power saving with wake-up patterns (ad-hoc)

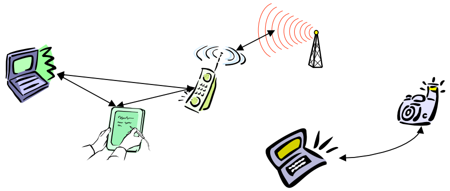


ATIM is the transmission map for ad hoc traffic: all stations stay awake for this slot

Bluetooth

- Standard is 802.15.1
- Basic idea
  - Universal radio interface for ad-hoc wireless connectivity
  - Interconnecting computer and peripherals, handheld devices, PDAs, mobile phones
  - Short range (10 m), low power consumption, license-free 2.45 GHz ISM
  - Voice and data transmission, approx. 1-3 Mbit/s gross data rate ((V3 offers 24Mbits)





History of Bluetooth

- History
  - 1994: Ericsson (Mattison/Haartsen), “MC-link” project
  - Renaming of the project: Bluetooth after Harald “Blåtand” Gormsen [son of Gorm], King of Denmark in the 10th century
  - 1998: foundation of Bluetooth SIG, www.bluetooth.org
  - 1999: erection of a rune stone at Ericsson/Lund ;-)
  - 2001: first consumer products for mass market, spec. version 1.1 released
  - 2005: 5 million chips/week

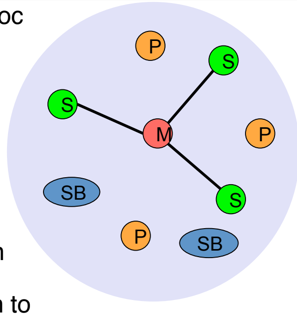
Bluetooth™

- Special Interest Group
  - Original founding members: Ericsson, Intel, IBM, Nokia, Toshiba
  - Added promoters: 3Com, Agere (was: Lucent), Microsoft, Motorola
  - > 10000 members
  - Common specification and certification of products

UNIVERSITY OF CAMBRIDGE

Piconet

- Collection of devices connected in an ad hoc fashion
- One unit acts as master and the others as slaves for the lifetime of the piconet
- Master determines frequency hopping pattern, slaves have to synchronize
- Each piconet has a unique hopping pattern
- Participation in a piconet = synchronization to hopping sequence
- Each piconet has **one master** and up to 7 simultaneous slaves (> 200 could be parked)

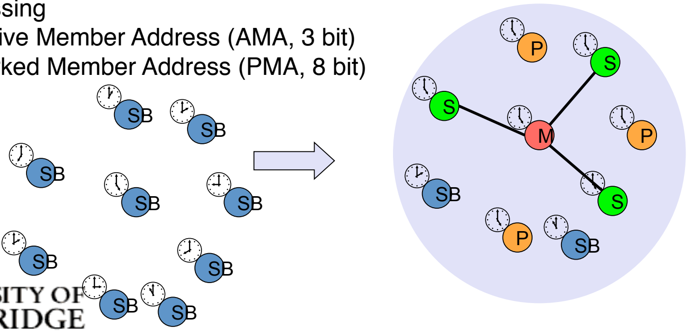


M=Master
S=Slave
P=Parked
SB=Standby

UNIVERSITY OF CAMBRIDGE

Forming a piconet

- All devices in a piconet hop together
  - Master gives slaves its clock and device ID
    - Hopping pattern: determined by device ID (48 bit, unique worldwide)
    - Phase in hopping pattern determined by clock
- Addressing
  - Active Member Address (AMA, 3 bit)
  - Parked Member Address (PMA, 8 bit)

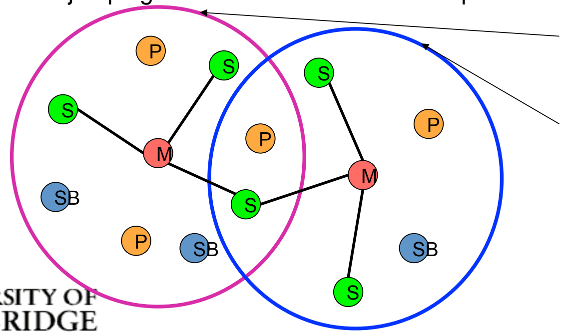


UNIVERSITY OF CAMBRIDGE

Scatternet

- Linking of multiple co-located piconets through the sharing of common master or slave devices
  - Devices can be slave in one piconet and master of another
- Communication between piconets
  - Devices jumping back and forth between the piconets

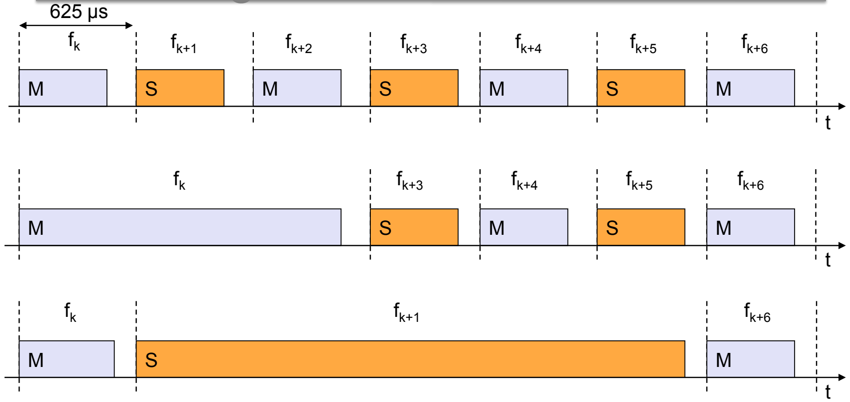
M=Master
S=Slave
P=Parked
SB=Standby



Piconets (each with a capacity of 720 kbit/s)

UNIVERSITY OF CAMBRIDGE

Frequency selection during data transmission



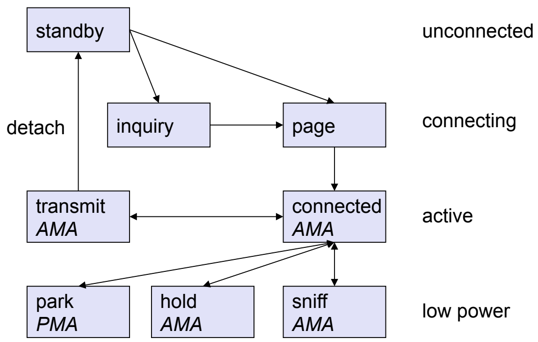
UNIVERSITY OF CAMBRIDGE

How to establish a piconet

- A device M starts an inquiry by sending an inquiry access code (IAC)
- Stand by devices listen periodically. When inquiry detected return packet containing its device address and timing information. The device is then a slave and enters the page mode
- After finding the required devices M sets up the piconet (hopping sequence, IDs). Slaves synch with M's clock.
- M can continue to page more devices
- Connection state:
  - Active state: transmit, receive and listening
    - All devices have AMA (active member address)
  - Passive state:
    - Sniff: listen at reduce rate but AMA kept
    - Hold: AMA kept but stop transmission
    - Park: release AMA and use PMA (parked). Still synched

UNIVERSITY OF CAMBRIDGE

Baseband states of a Bluetooth device



Standby: do nothing
Inquire: search for other devices
Page: connect to a specific device
Connected: participate in a piconet

UNIVERSITY OF CAMBRIDGE

Park: release AMA, get PMA
Sniff: listen periodically, not each slot
Hold: stop ACL, SCO still possible, possibly participate in another piconet

Ad Hoc Networking

- We have seen connectivity between wireless devices and fixed basestations through
  - WIFI
  - Cellular
- WIFI and Bluetooth provide [also] ad hoc connectivity modes where there is no infrastructure supporting the communication

UNIVERSITY OF CAMBRIDGE

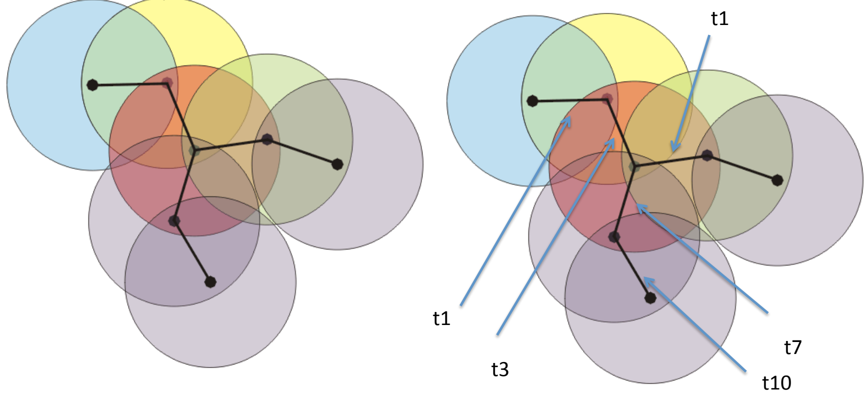
Examples of Multi-hop Ad hoc Networks

UNIVERSITY OF CAMBRIDGE

Connected vs Disconnected Ad Hoc Networks

Connected: there is a connected path among each couple

Disconnected: there is no connected path, just sometimes some temporal ones



UNIVERSITY OF CAMBRIDGE

Routing in Wired/Wireless Networks

- Link State
  - Each node sends its link information to all nodes in the network
  - Small vector to all large number of nodes
  - Dijkstra for shortest path
- Distance Vector
  - Each node sends its table to its neighbours
  - Large vector to small number of nodes
  - Bellman Ford for shortest path

UNIVERSITY OF CAMBRIDGE

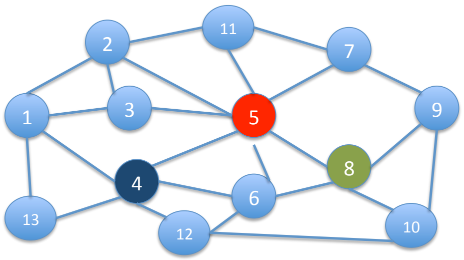
OLSR: Optimized Link State Routing Protocol

- Proactive
- Hello messages from a node to its neighbours with bidirectional links and list of known neighbours -> learning 2 hop neighbourhood
- Ask a subset of neighbours to forward a node's link state (subset=MPR, Multipoint Relay)
- If node X is in your MPR you are in X's MPR Selector
- Each MPR has a set of MPR Selectors
- Each node sends LS to all its neighbours
- MPR forwards LS of MPR's selectors
- Nodes use this info for routing tables but do not forward

UNIVERSITY OF CAMBRIDGE

OLSR Example

- Node 5 has selected 4 and 8 as MPR and sends LS to 2,3,4,6,7,8,11
- Nodes 2,3 6,7,11 use this info but do not forward
- Node 4 forwards to 1,6,12,13
- Node 8 forwards to 6,9,10



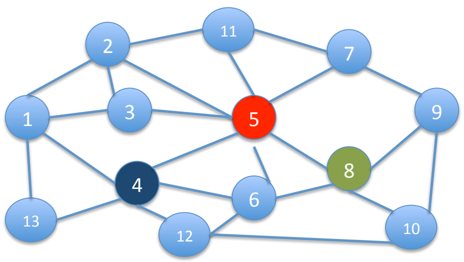
How are MPR Selected?

- MPR are arbitrarily selected
- A node can put all its neighbours into a MPR but
  - Not optimized -> lots of duplication
  - Optimal: min set such that all 2-hop neighbours get node's LS
  - Finding optimal MPR is NP complete
  - Heurisitics
    - N1(x)=1-hop neighbours
    - N2(x)=2-hop neighbours not covered
    - MPR(x)= empty
    - From N1(x)-MPR(x), select node A that has max connectivity to uncovered nodes (and update N2(x))
    - Add A to MPR(x)

UNIVERSITY OF CAMBRIDGE

Link State forwarding

- Each node maintains a routing table with
  - Node id, next hop, distance
- The table is never forwarded
- Updates on links are forwarded when there is a topology change



UNIVERSITY OF CAMBRIDGE

Drawbacks of OLSR (and partly of ad hoc protocols)

- Assumes a connected network
- Assumes bidirectional links
  - Extensions have been proposed to consider link quality and bidirectionality
- Being proactive means it consumes a lot of resources

UNIVERSITY OF CAMBRIDGE

Summary

- In this lecture we have introduced the Wireless LAN and Bluetooth standard and we have started to describe concepts related to ad hoc networking and routing.

UNIVERSITY OF CAMBRIDGE