A MAC for Cooperative Communications

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MNET Lab

Outline

- Introduction
- CoopMAC
- Performance evaluation
- Discussion
- References

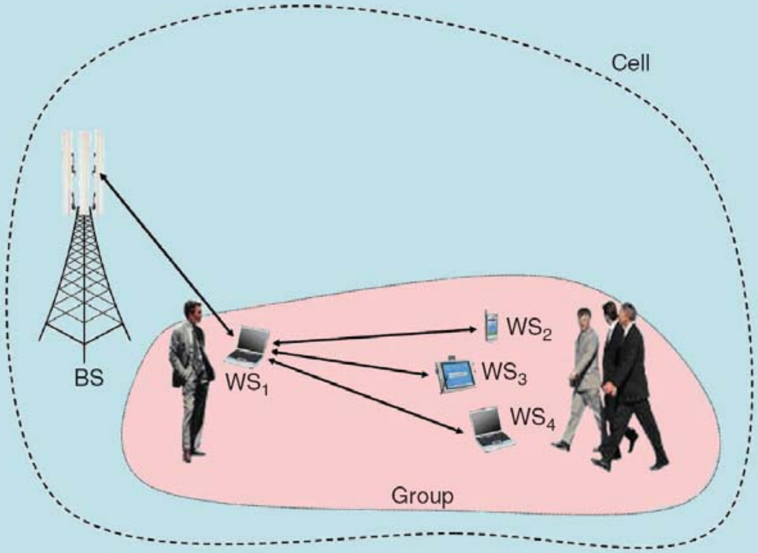


Fig. 2. Gateway functionality.

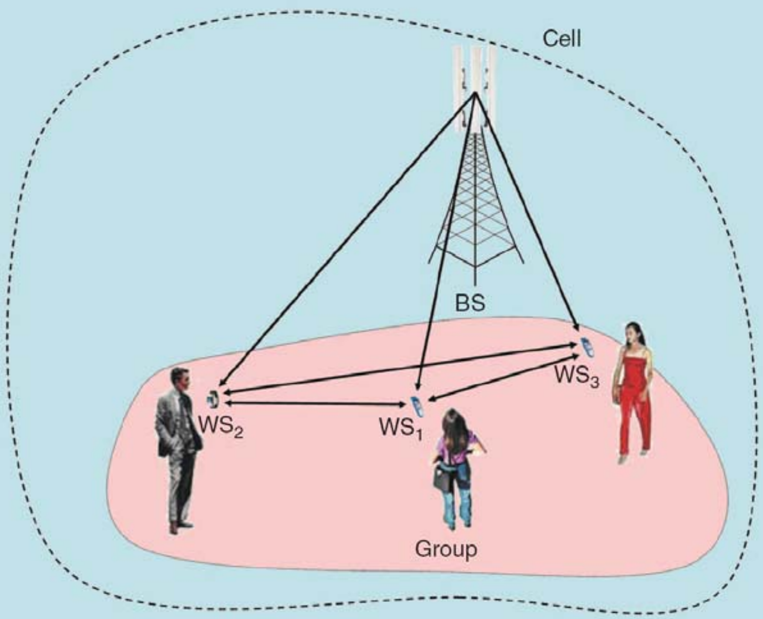


Fig. 3. Cooperative service support by customer diversity.

Cooperative Services

- Cost down
  - Resource sharing
  - Wireless gateway
- Power Saving
  - Local transmission

Cooperative Services

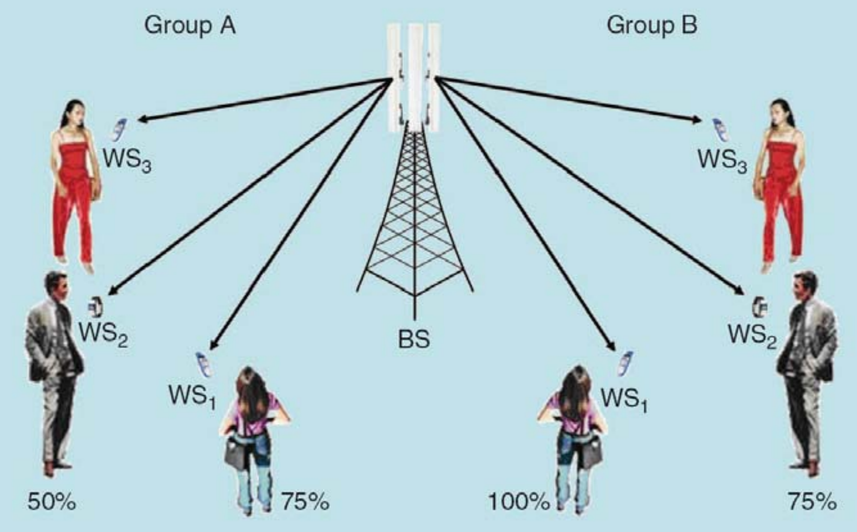


Fig. 4. Example of percentage of data correctly received.

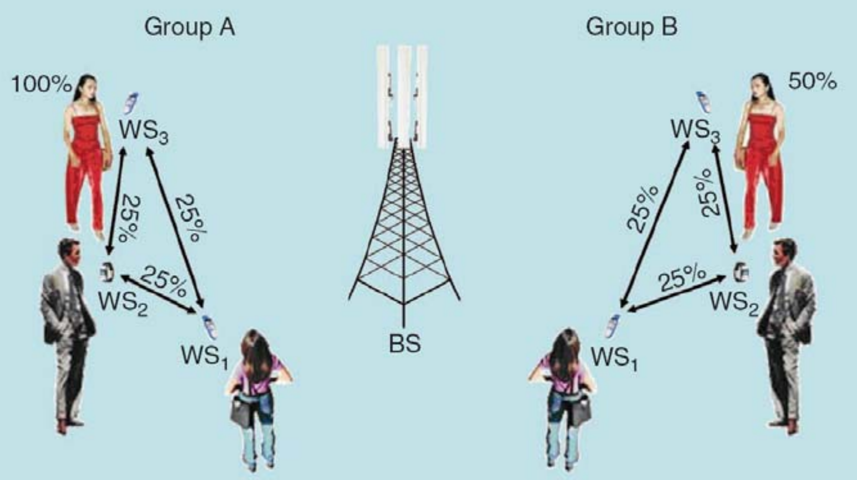


Fig. 5. Example of triangular retransmission.

- Cell capacity enhancement
  - Local retransmission
  - Higher modulation
- (Cluster establishment)
  - Retransmission scheduling
  - Network Coding
- (Relaying node deployment)

Motivations

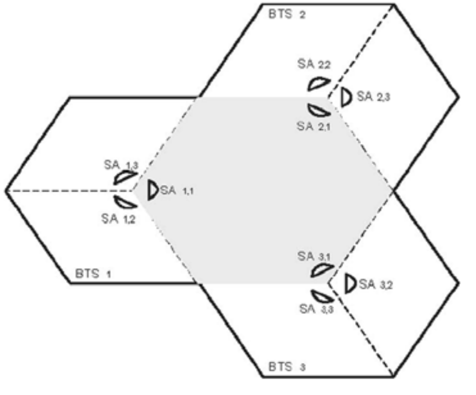
- Overhearing
  - The broadcast nature of wireless communications enables a neighboring node to perform further operations in order for spatial diversity, robustness, and network coding etc.
- Unstable direct links
  - Lowered throughput or unavailable service
  - A third station acts as a virtual antenna
- Slow stations
  - Lowered throughput due to the longer transmission time used by slow stations
  - High rate stations help slow stations

CoopMAC

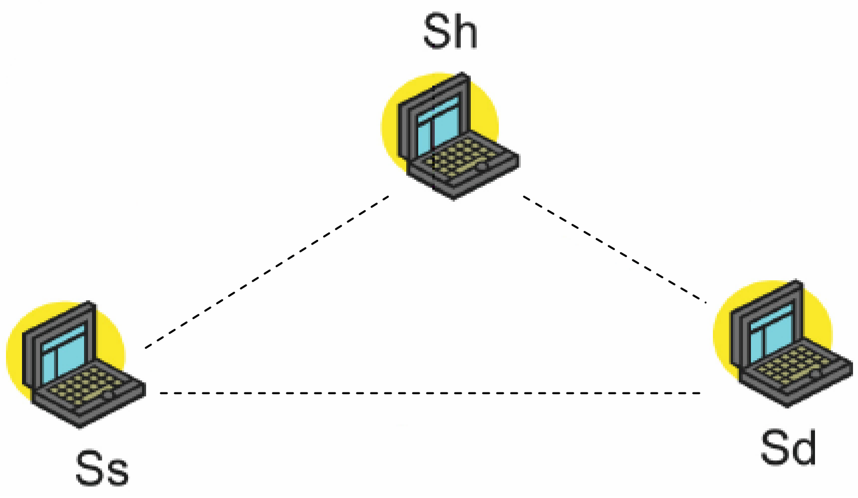
- CoopMAC, in which high data rate stations assist low data rate stations in their transmissions, is proposed.
- CoopMAC achieves both higher throughput and lower interference.
- CoopMAC is simple and backward compatible with the legacy 802.11.

Related Works

- [12]: cooperative collision resolution
- divert[13]: AP selection
- rPCF[14]: multihop PCF
- rDCF[15]: similar to CoopMAC
- RAAR[17]: centralized selection of relay nodes
- M. Dianati et al., “Cooperative Fair Scheduling for the downlink of CDMA Cellular Networks,” *IEEE Trans. Vehicular Technology*, vol. 56, no. 4, July 2007.
  – Cooperation of base stations with sectored antennas



Helper Detection



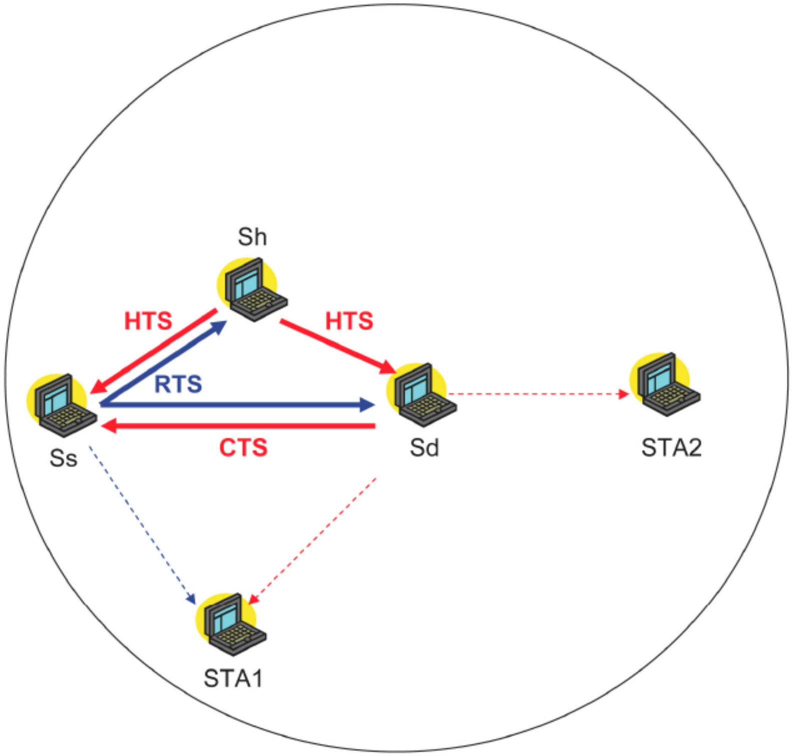
- Overhearing
  - data packet header
  - RTS/CTS/ACK
- Threshold

$$\frac{8L}{R_{sh}} + \frac{8L}{R_{hd}} + T_{PLCP} + T_{SIFS} < \frac{8L}{R_{direct}}$$

- CoopTable
  - ID, Latest Time, Rsh, Rhd, # failure.

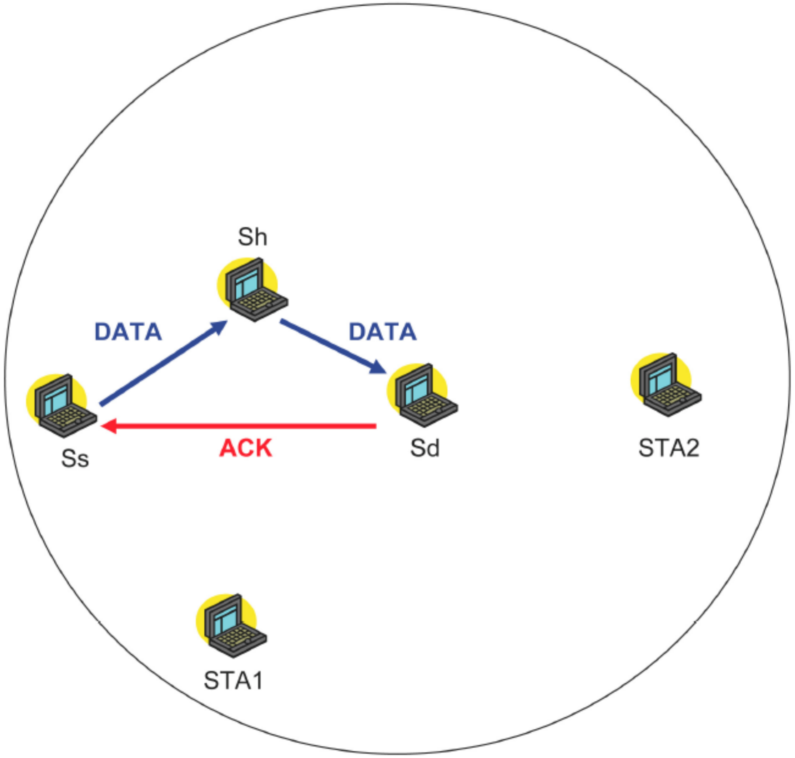
Operations

control frame exchange
(RTS/HTS/CTS mode)

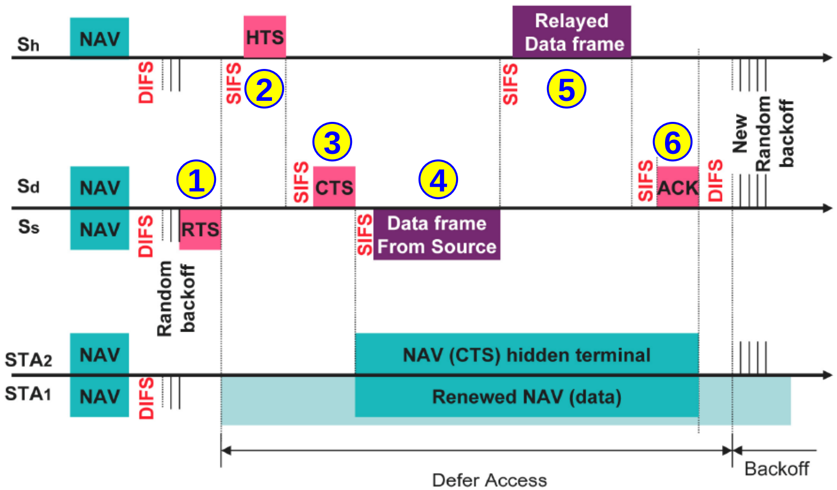


HTS: Helper-ready to Send

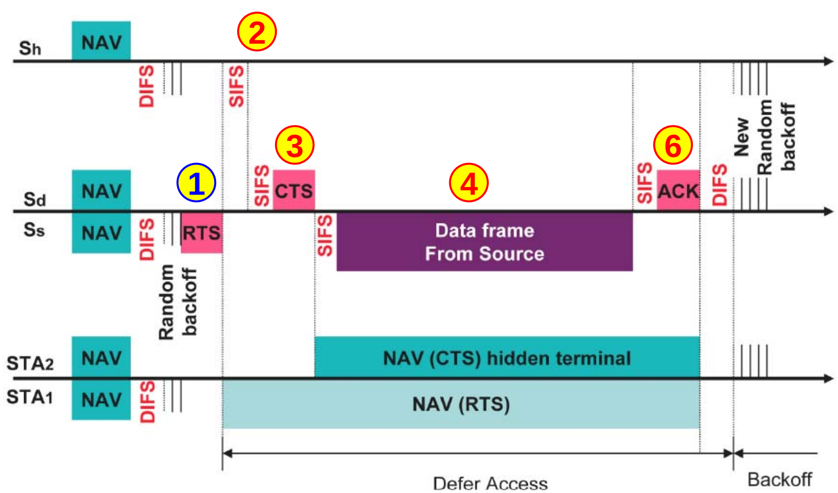
data frame exchange
(base mode)



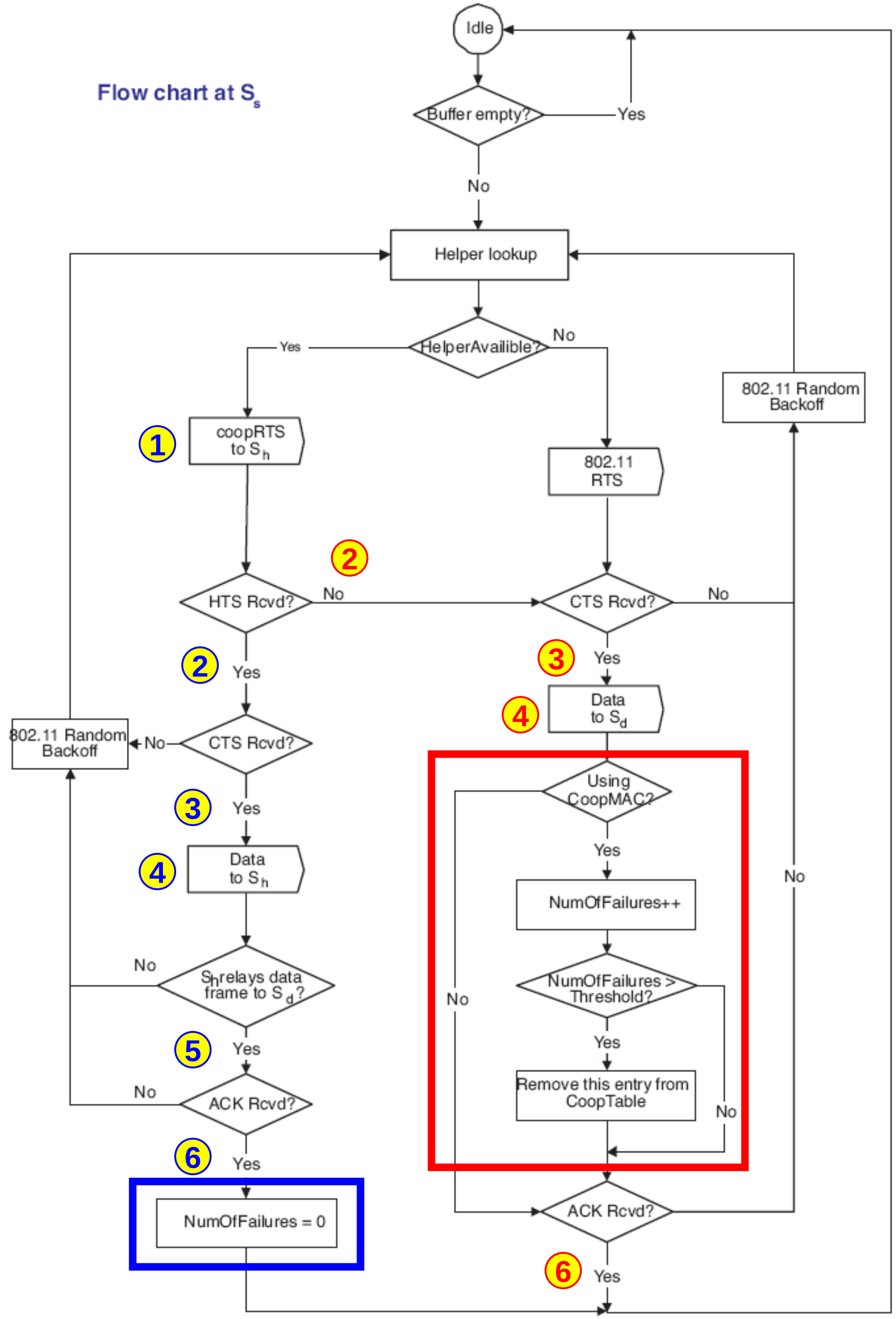
CoopMAC w/ helper



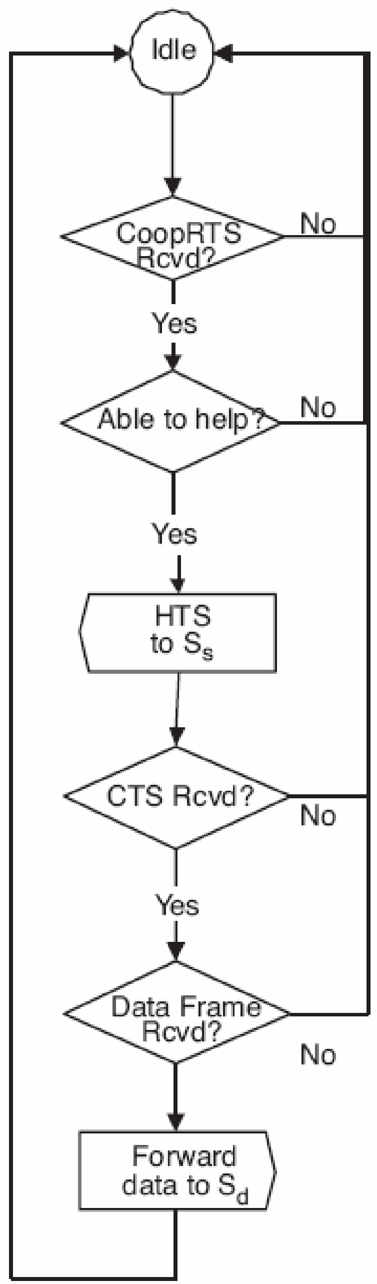
CoopMAC w/o helper



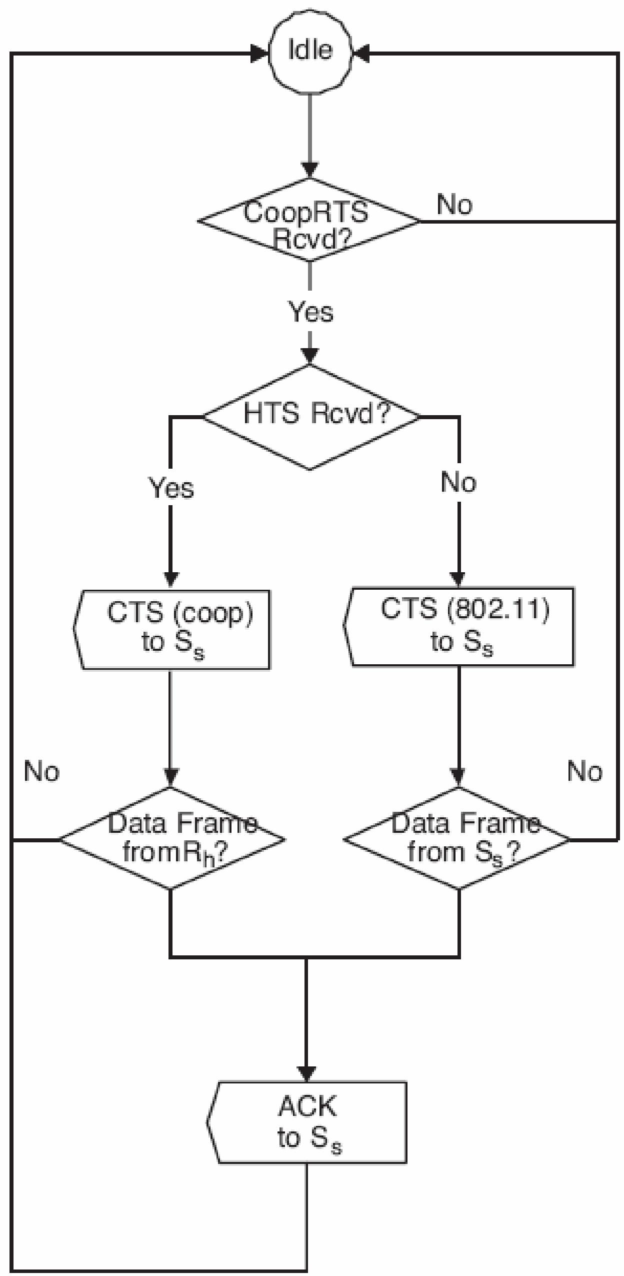
Flow chart at S_s



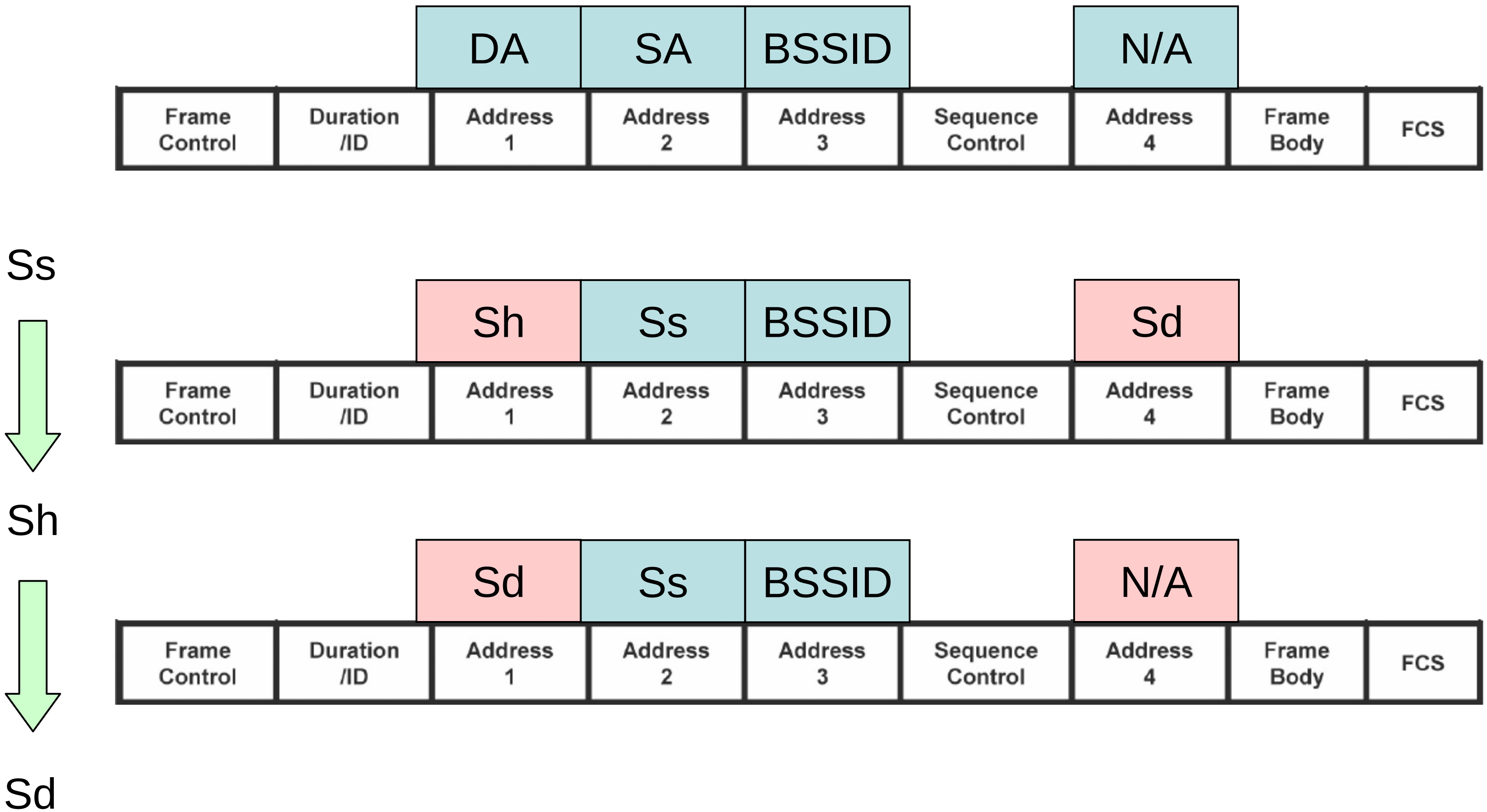
Flow chart at S_h



Flow chart at S_d



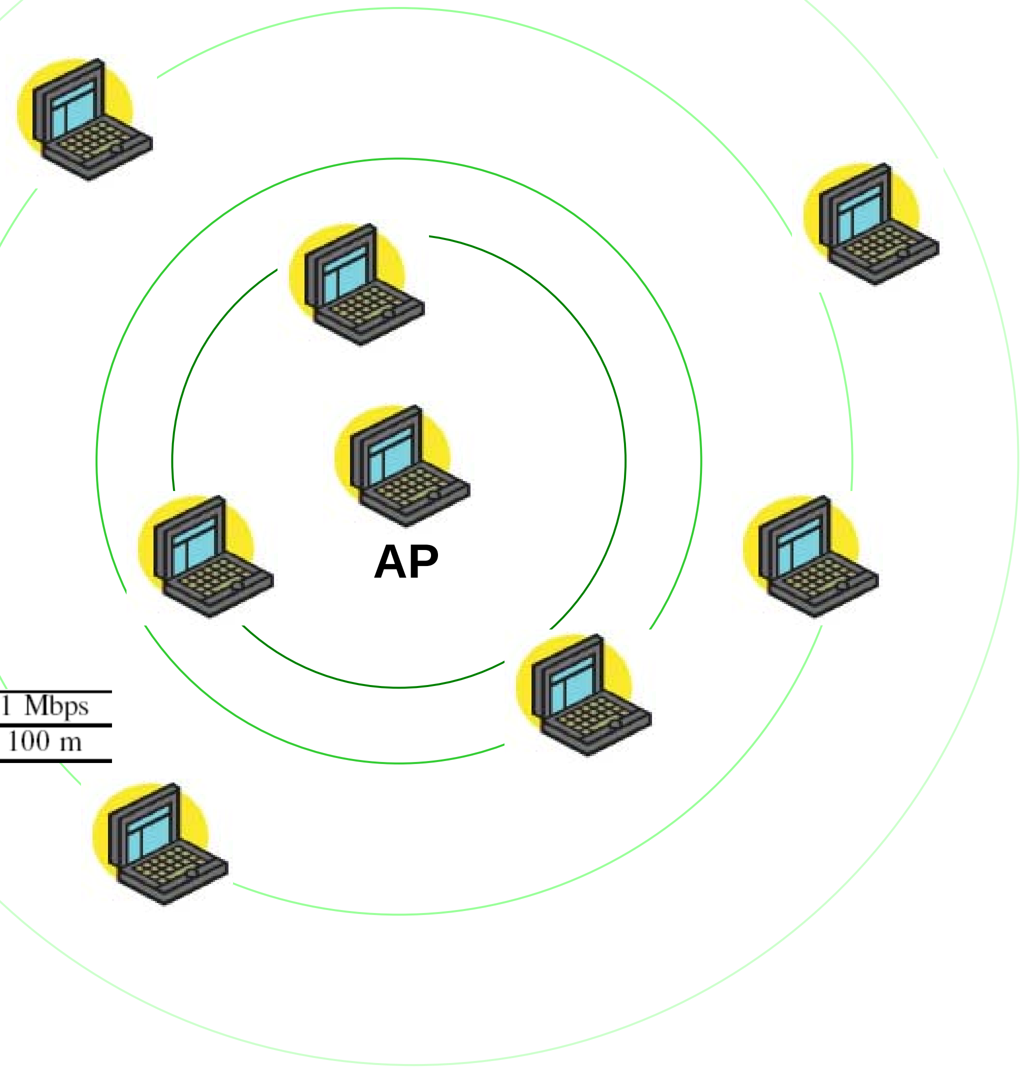
Base Mode


DA
SA
BSSID
N/A
Frame Control
Duration /ID
Address 1
Address 2
Address 3
Sequence Control
Address 4
Frame Body
FCS
Ss
Sh
Ss
BSSID
Sd
Frame Control
Duration /ID
Address 1
Address 2
Address 3
Sequence Control
Address 4
Frame Body
FCS
Sh
Sd
Ss
BSSID
N/A
Frame Control
Duration /ID
Address 1
Address 2
Address 3
Sequence Control
Address 4
Frame Body
FCS
Sd

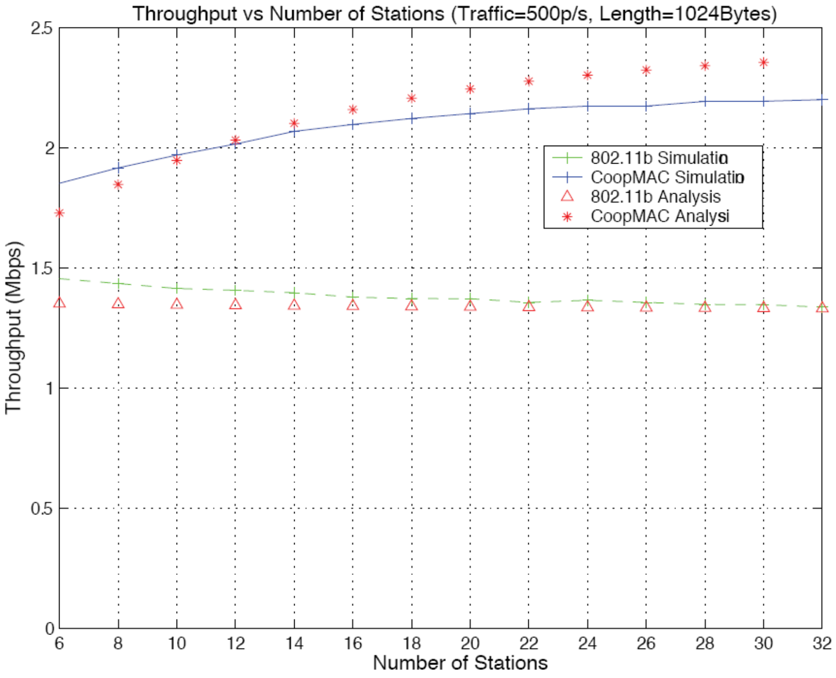
Simulation Setup

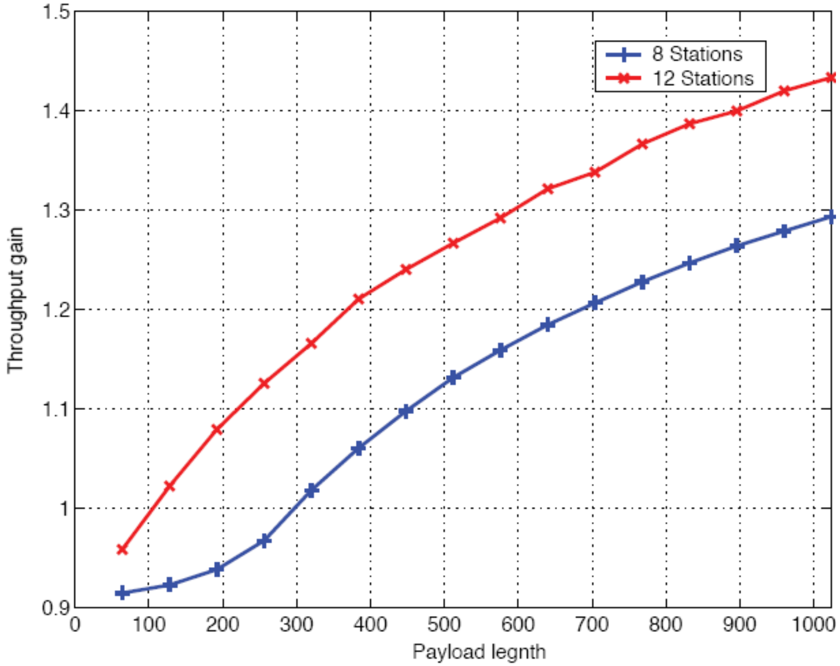
MAC header	272 bits
PHY header	192 bits
RTS	352 bits
CTS	304 bits
ACK	304 bits
Data rate for MAC and PHY header	1 Mbps
Slot time	20 μ s
SIFS	10 μ s
DIFS	50 μ s
aCWMin	31 slots
aCWMax	1023 slots
retryLimit	6

Data Rate	11 Mbps	5.5 Mbps	2 Mbps	1 Mbps
Range ($BER \geq 10^{-5}$)	48.2 m	67.1 m	74.7 m	100 m



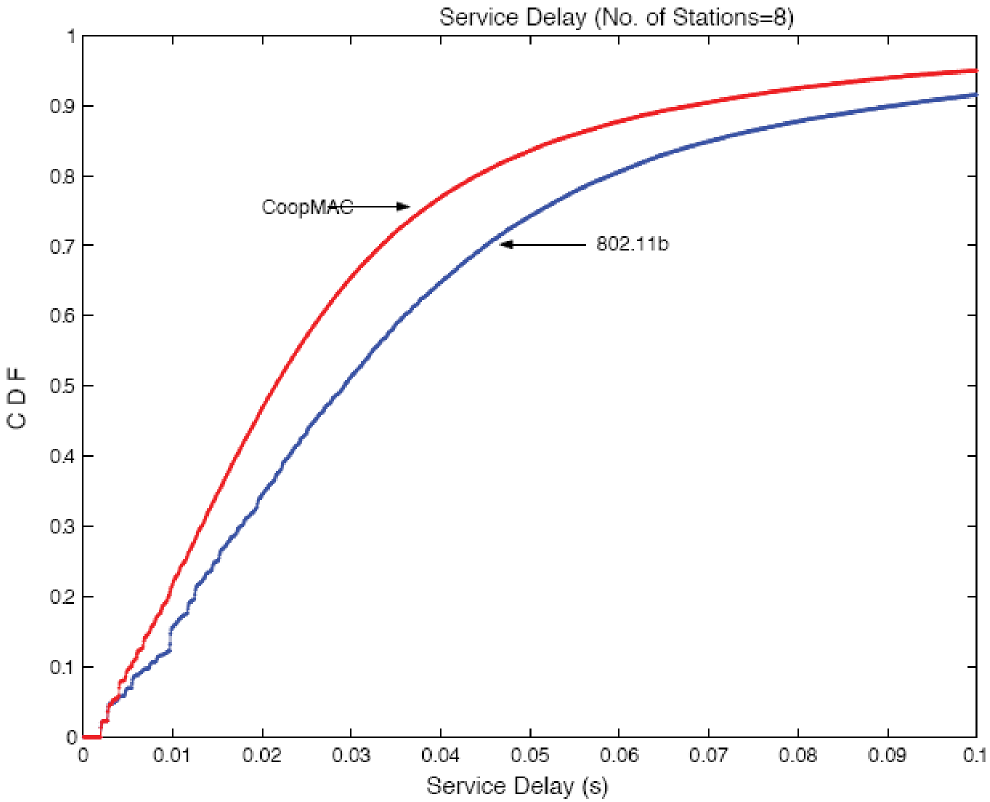
Throughput



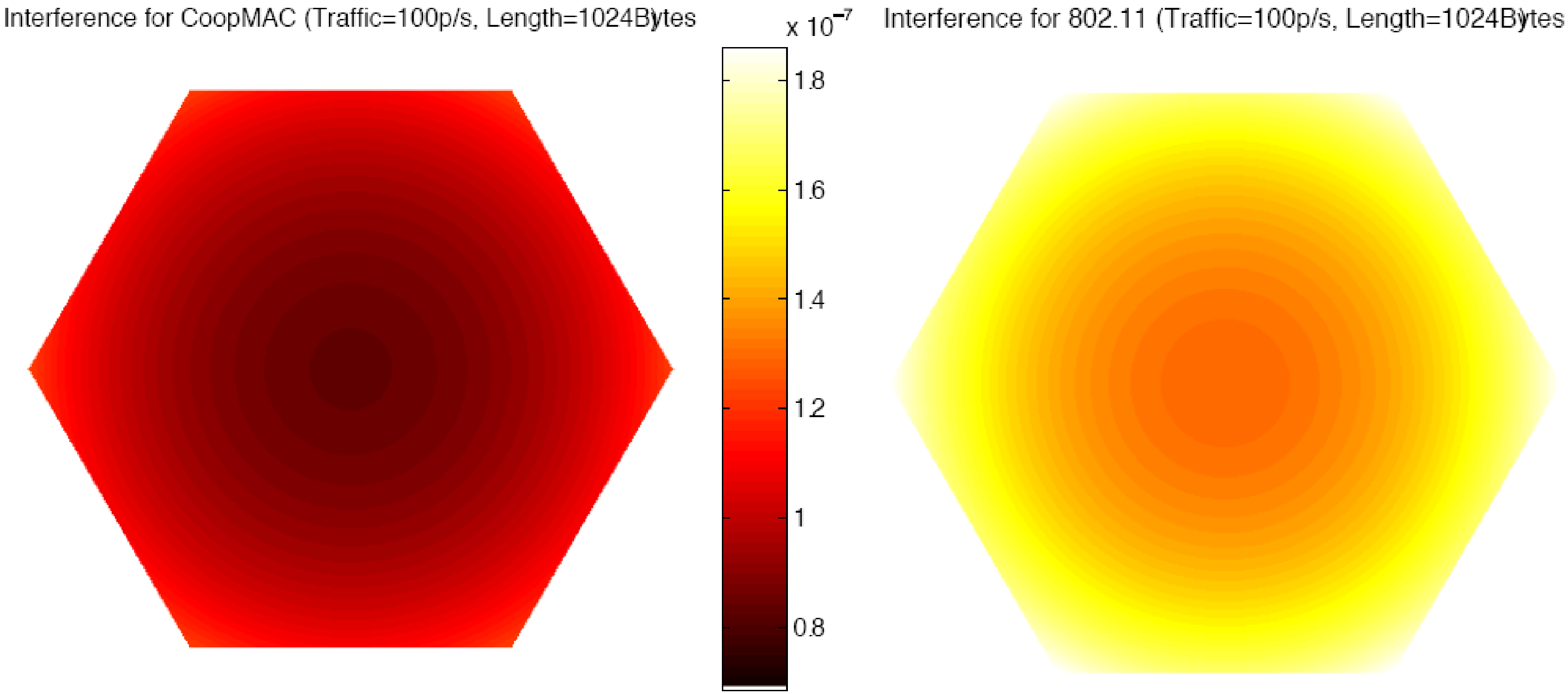


Gain = CoopMAC/802.11

Channel Access Delay



Interference under Dense Deployment



35% improvement

Power Consumption

- under a saturated network

BITS-PER-JOULE (PKT LENGTH = 1024 BYTES).

11 Mbps node	W/o forw(x 10^4)b	With forw(x 10^4)b
Analysis	8.2845	8.8909
Simulation	7.8552	8.7389
5.5 Mbps node	W/o forw(x 10^4)b	With forw(x 10^4)b
Analysis	8.1544	8.2206
Simulation	7.7032	8.4592

[11] S. Narayanan et al., "To forward or not to forward – that is the question," to appear in *Special Issue on Cooperatino in Wireless Networks, Springer – Wireless Personal Communications*.

Summary

- Cooperation at the MAC
  - Higher throughput
  - Lower delay
  - Less interference under a dense deployment
  - Reduced energy consumption

- CoopMAC achieves better performance as # stations increases.

Discussions(1/4)

- Backward compatible?
  - FF(HTS) = FF(CTS)
  - FF(CoopRTS) $\neq$ FF(RTS)

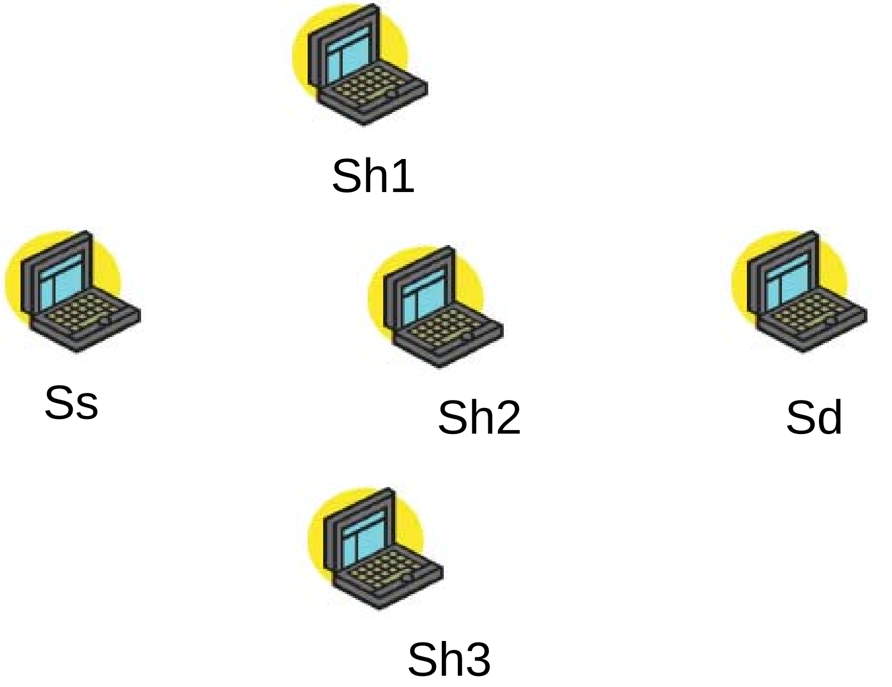
Frame Control	Duration	RA	TA	Helper ID (6 octes)	R_{sh} (1 octet)	R_{hd} (1 octet)	FCS

Frame Control	Duration	RA	TA	FCS

- How to identify that a neighboring node is CoopMAC capable?
  - Data (101000) vs. RTS/CTS/HTS (010000-011001)?

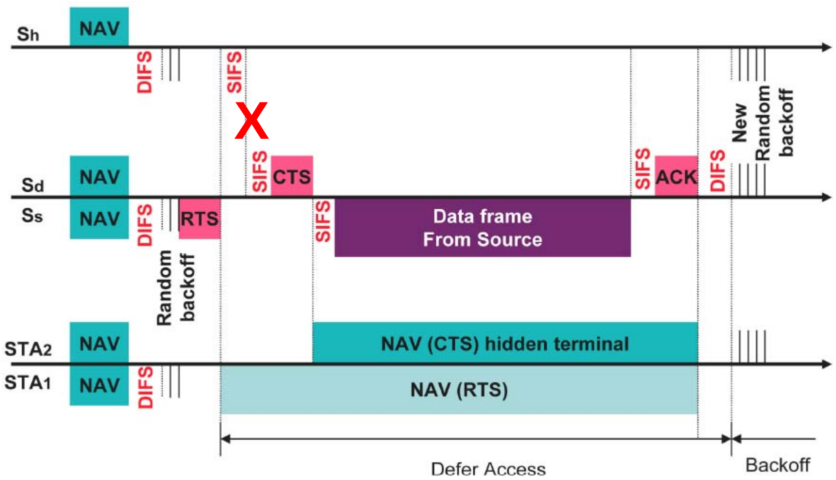
Discussions(2/4)

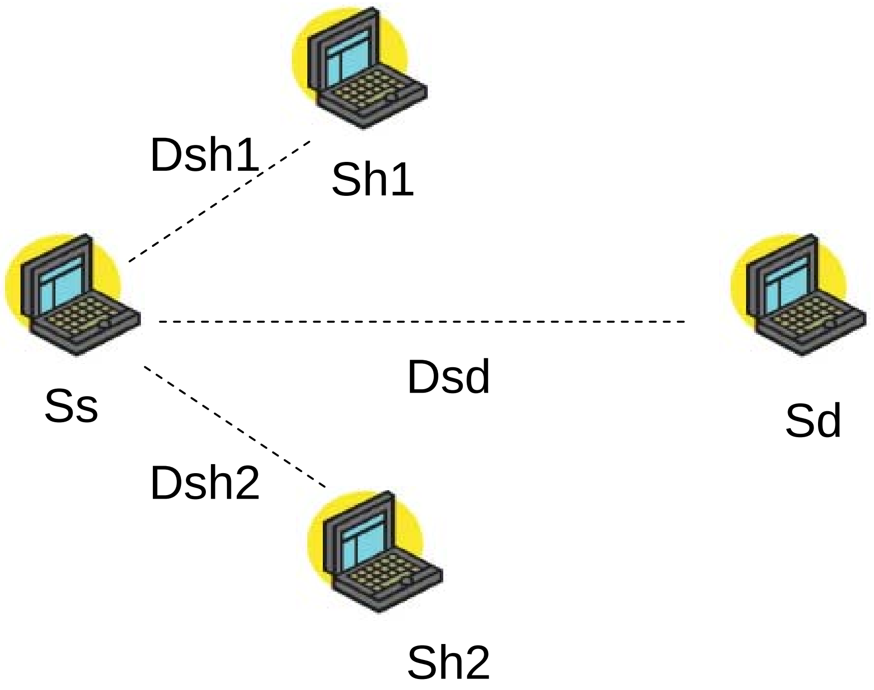
- Helper selection
  - Sender-oriented
    - Single chance problem
  - >Helper oriented?
    - Collision resolution



Discussions(3/4)

- Delayed CTS (2*SIFS)
  - Dshx ≈ Dsd
  - Dshx << Dsd?





Discussions(4/4)

- Cross-layer design
  - PHY PLCP
  - Alternative route
    - Network-layer integration?

- Mobility concerns

Cooperative Services

- QoS enhancement (Multiple Description Coding)

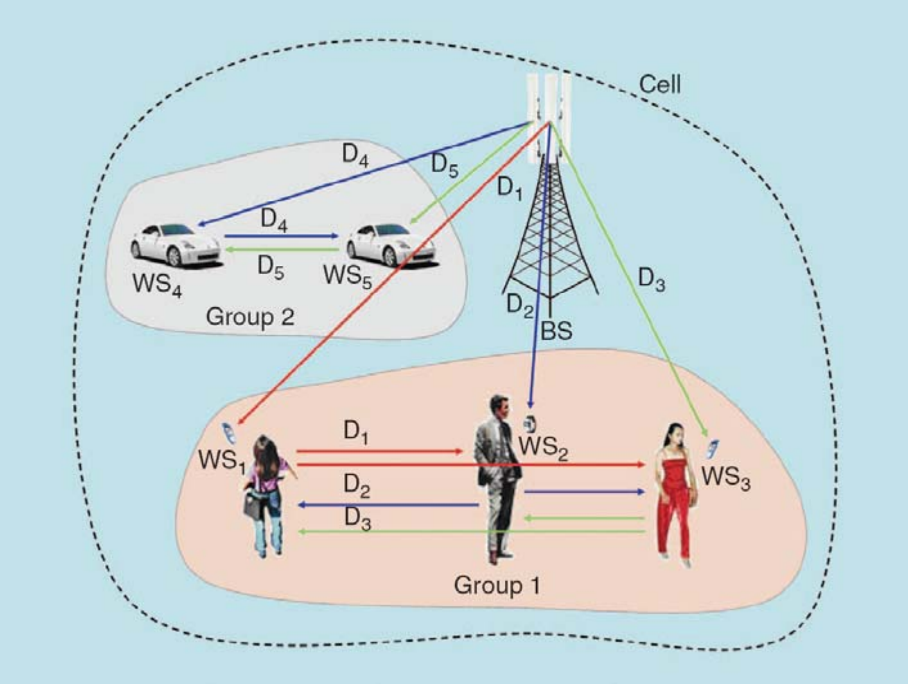


Fig. 6. Increased video quality by customer accumulation.

BS: Base Station;
WS: Wireless Station;
Dx: Descriptor x;

Mobile Relaying Services

- Dedicated taxi ride
- Shared taxi ride
  - (Course planning)

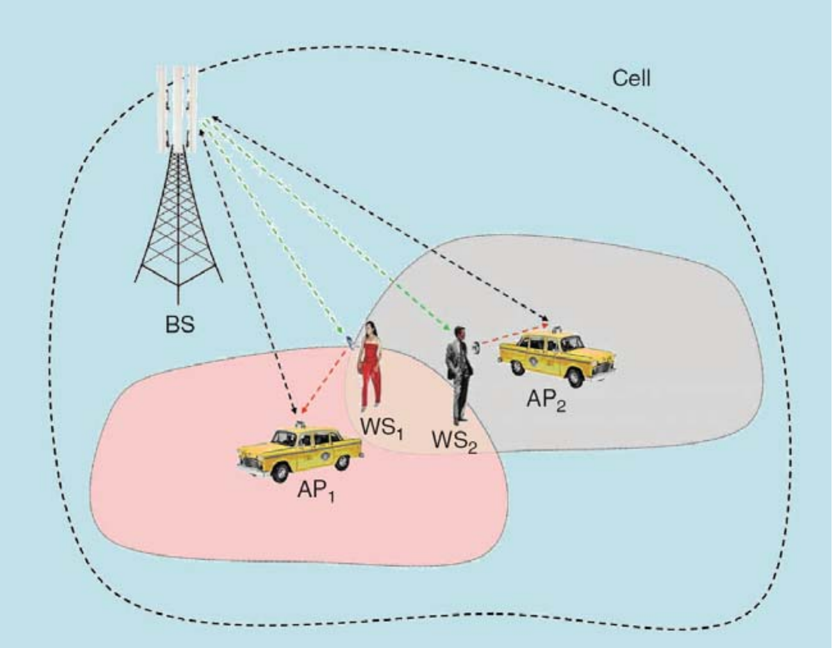


Fig. 9. Dedicated taxi ride.

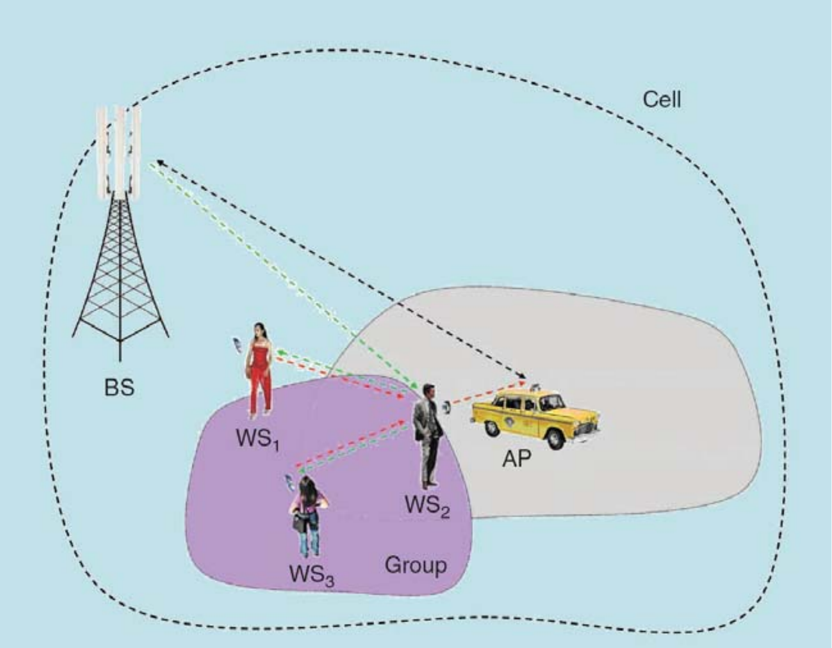


Fig. 10. Shared taxi ride.

CoopNet?

Key
Starbucks Wi-Fi Hot Spot
BT Openzone Wi-Fi Hot Spot
Megabeam Wi-Fi Hot Spot
UK Explorer Wi-Fi Hot Spot
Underground Station
Mainline Station
City of London boundary
NORTH
B59
S6
FARRINGDON
802.16(SS)
802.11(AP)
802.11(MS)
MOORGATE
B61
802.16(SS)
802.11(AP)
802.11(MS)
802.16(SS)
802.11(AP)
S4
B60
802.11(MS)
802.16(BS)
ST. PAULS
802.11(MS)
802.11(MS)
B62
802.16(SS)
802.11(AP)
BLACKFRIARS
802.16(SS)
802.11(AP)
802.16(SS)
802.11(AP)
B58
CANNON STREET
802.11(MS)
802.16(BS)
802.16(SS)
802.11(AP)
S5
FENCHURCH STREET
802.16(SS)
802.11(AP)
802.11(MS)

References

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