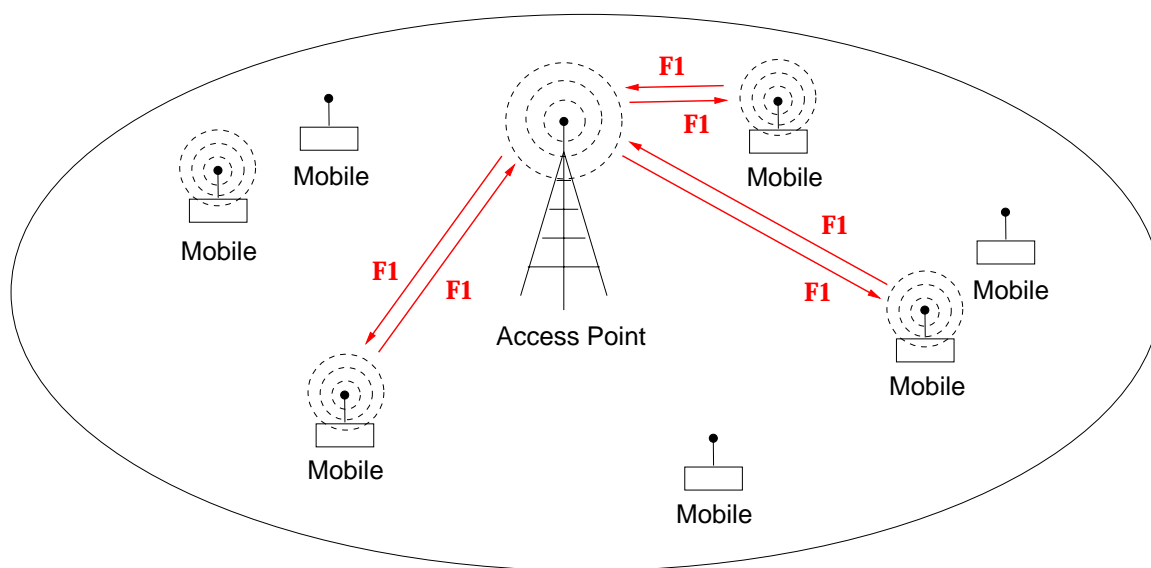


## Wireless LAN (WLAN): infrastructure mode

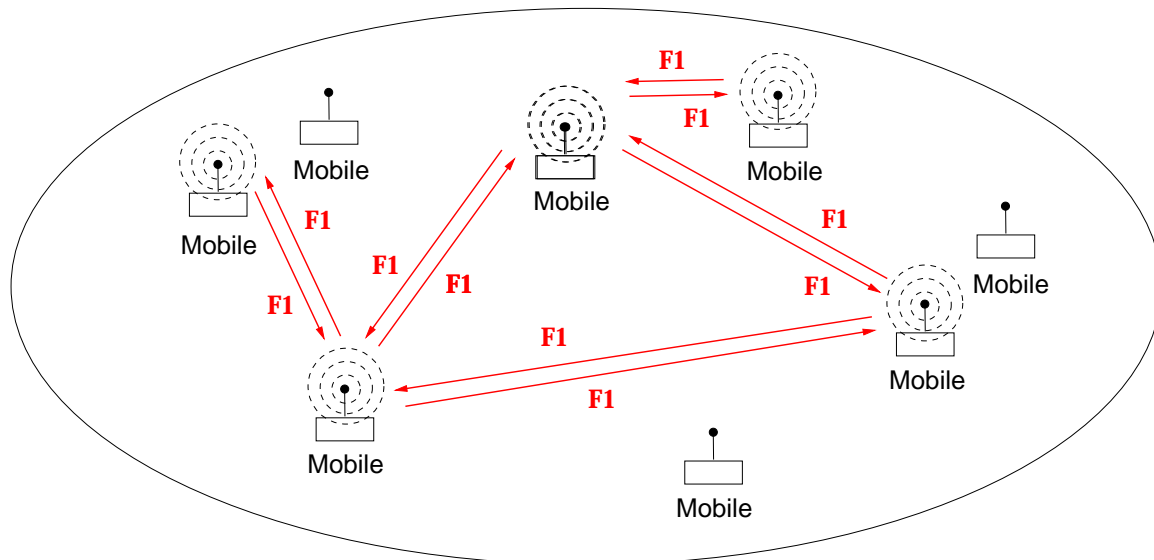


WLAN: Infrastructure Network

→ shared uplink & downlink channel  $F1$

- basic service set (BSS)
- SSID (service set identifier): name/label of BSS
- base station: access point (AP)
- mobile stations must communicate through AP

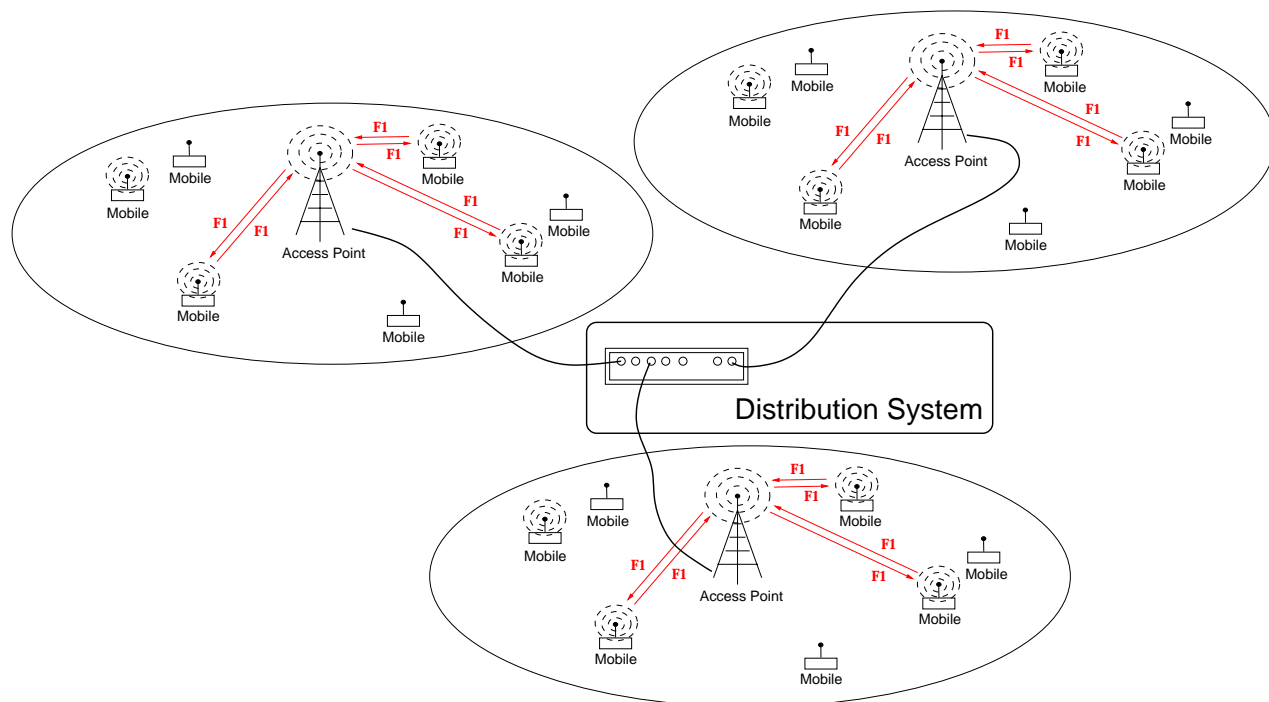
## WLAN: ad hoc mode



WLAN: Ad Hoc Network

- homogeneous: no base station
- everyone is the same
- share forwarding responsibility
- independent basic service set (IBSS)
- mobile stations communicate peer-to-peer
  - also called peer-to-peer mode

## WLAN: internetworking



### WLAN: Extended Service Set

→ internetworking between BSS's through APs

→ mobility and handoff

- extended service set (ESS): shared SSID
- APs are connected by distribution system (DS)
  - typically: Ethernet switch

- How do APs and Ethernet switches know where to forward frames?
  - spanning tree
  - IEEE 802.1 (Perlman's algorithm)
  - learning bridge: source address discovery
  - per interface: log source MAC address of incoming frames
  - initially or if unclear: broadcast
  - a very simple form of routing
  - adequate for small systems

Additional headache: mobility

- also called roaming
- how to perform handoff
- mobility management at MAC vs. IP

Mobility between BSS's in an ESS

- association
  - registration process
  - AP sends out periodic beacon frame
  - mobile station (MS) associates with one AP
- disassociation
  - upon permanent departure: notification

Handoff from old to new AP:

- reassociation
  - movement of MS from one AP to another
  - client initiated
  - e.g., AP's signal strength is low
  - passive (beacon) or active (probe) scanning to find alternate AP
  - go through association process
  - inform new AP of old AP
  - forwarding of buffered frames from old to new AP in ESS

Note: when and parts of how to perform handoff are not part of IEEE standard

→ vendor dependent

IEEE 802.11b/g WLAN spectrum 2.4–2.4835 GHz:

- 11 channels (U.S.)
- 2.412 GHz, 2.417 GHz, ..., 2.462 GHz
- unlicensed ISM (Industrial, Scientific, Medical) band
- global: 2.4–2.4835 GHz
- up to 14 channels (e.g., Japan)

IEEE 802.11a: 5.15–5.35 GHz and 5.725–5.825 GHz

- UNNI (unlicensed National Information Infrastructure)
- non-global

IEEE 802.11n: both 2.4 and 5 GHz

- 2.4 GHz: backward compatible
- also uses multiple antennae
- called MIMO (multiple input multiple output)
- e.g., Apple's 802.11n has 3 antennae

Non-interference specification for 802.11b:

- each channel has 22 MHz bandwidth
- require 25 MHz channel separation
  - thus, only 3 concurrent channels possible
  - e.g., channels 1, 6 and 11
  - 3-coloring...



IEEE 802.11 WLAN MAC: uses CSMA

→ multi-user bandwidth sharing

However:

- 802.11b: uses DSSS CDMA
  - 11-bit chip sequence (Barker sequence)
  - single-user DSSS
  - why?

- 802.11a/g/n: uses OFDM
  - single-user OFDM (i.e., not OFDMA)
  - also called single-carrier (vs. multi-carrier)
  - 802.11g: 48 carrier frequencies
  - subcarrier separation: 312.5 KHz
  - bits of single frame are distributed across 48 subcarriers
  - first bit on subcarrier 1, second bit on subcarrier 2, etc.
  - but: transmission is sequential—not parallel!
  - similar to FHSS
  - why use OFDM without parallel speed-up?

Why not use OFDMA?

## IEEE 802.11 MAC

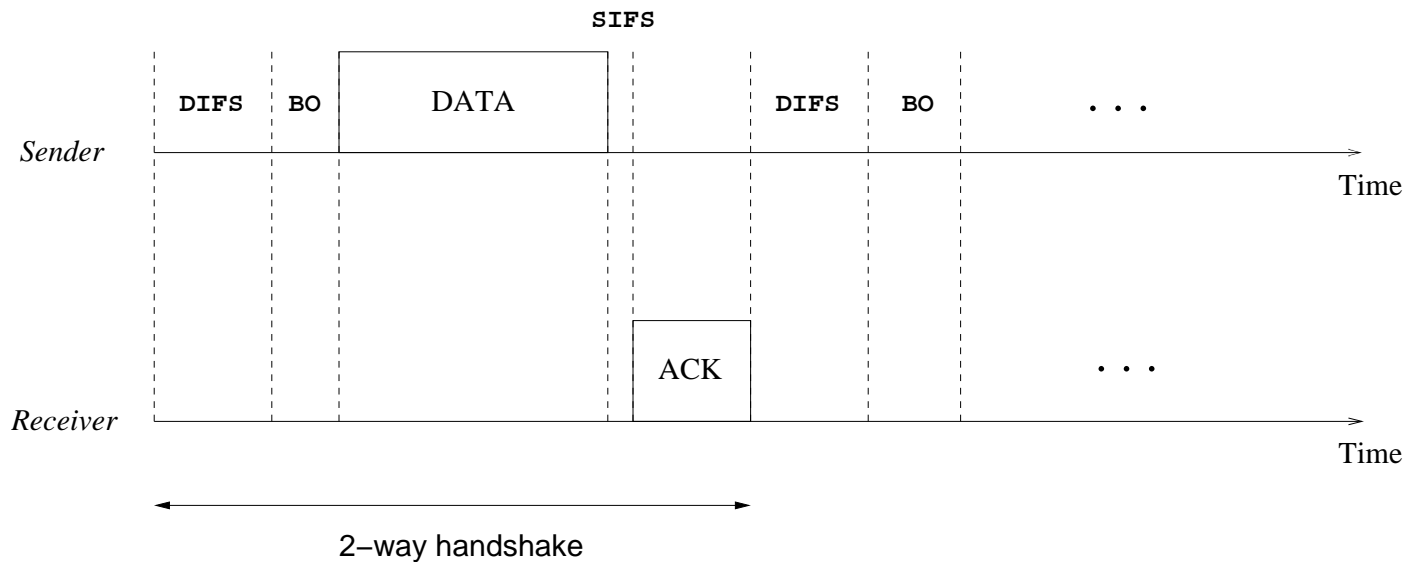
- CSMA/CA with exponential backoff
- almost like CSMA/CD
- drop CD
- explicit positive ACK frame
- added optional feature: CA (collision avoidance)

Two modes for MAC operation:

- Distributed coordination function (DCF)
  - multiple access (default mode)
- Point coordination function (PCF)
  - polling-based priority

... neither PCF nor CA used in practice

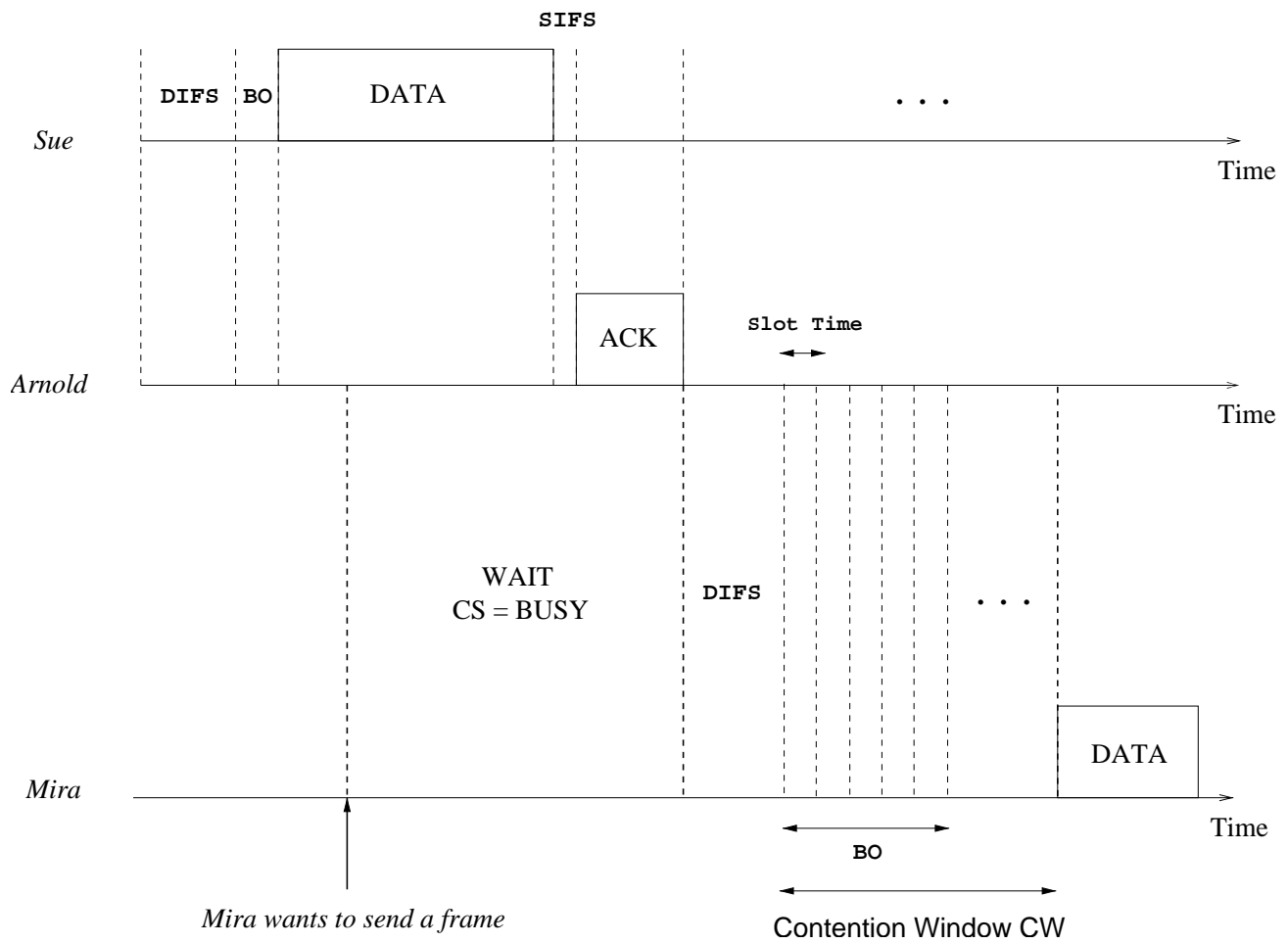
Timeline without collision:



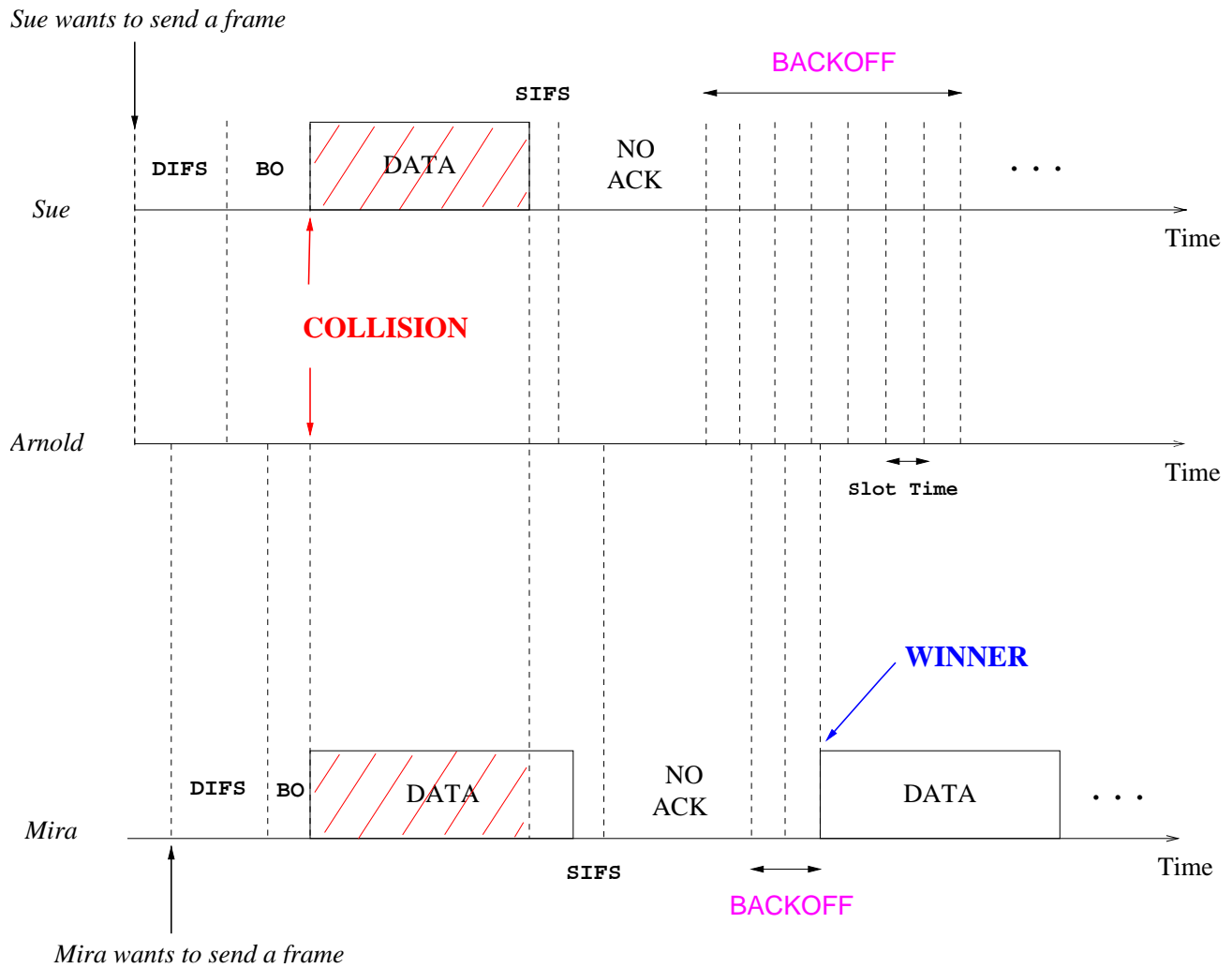
- SIFS (short interframe space):  $10 \mu s$
- Slot Time:  $20 \mu s$
- DIFS (distributed interframe space):  $50 \mu s$   
 $\rightarrow \text{DIFS} = \text{SIFS} + 2 \times \text{slot time}$
- BO: variable back-off (within one CW)  
 $\rightarrow \text{CWmin}: 31; \text{CWmax}: 1023$

Time snapshot with Mira-come-lately:

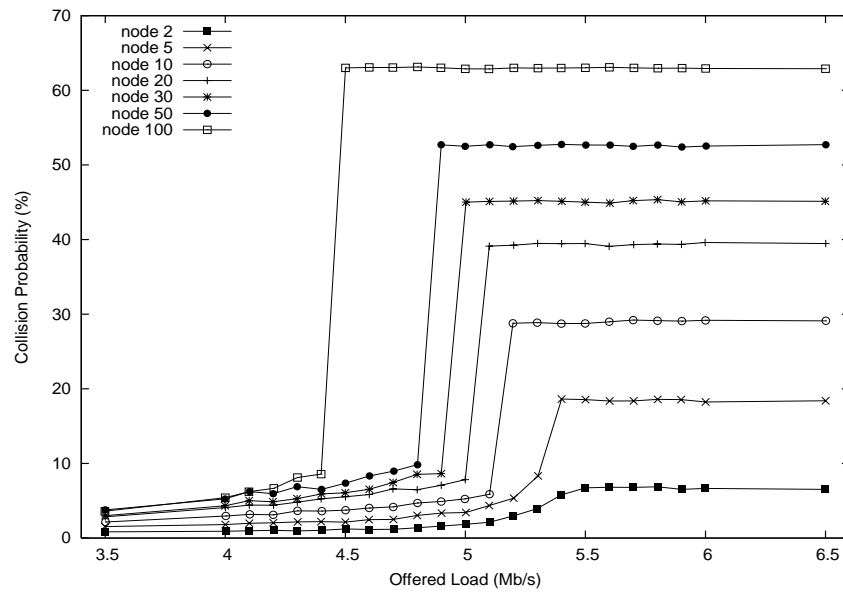
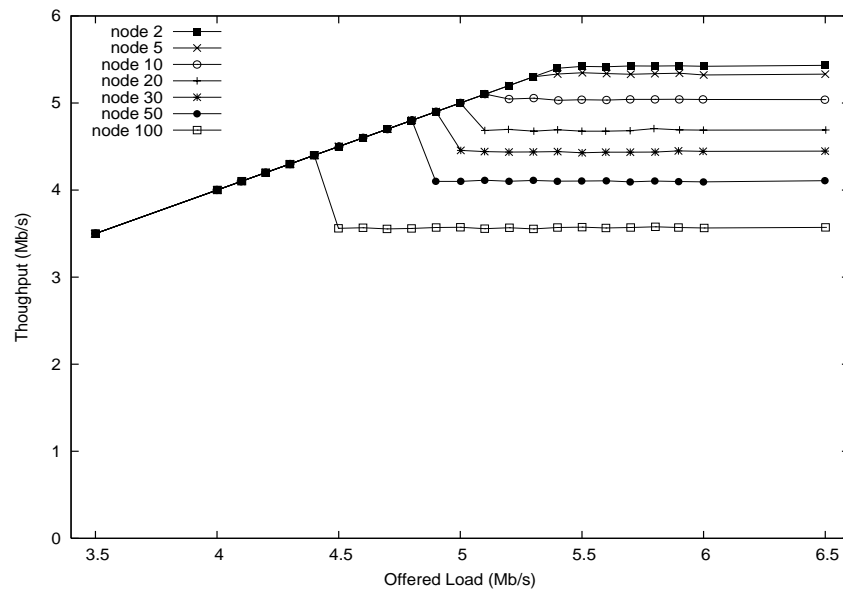
→ Sue sends to Arnold



### Time snapshot with collision (Sue & Mira):



# MAC throughput and collision (simulation):



MAC throughput (experiment):

→ HP iPAQ pocket PC running Linux

