Wireless TDMA Mesh Networks

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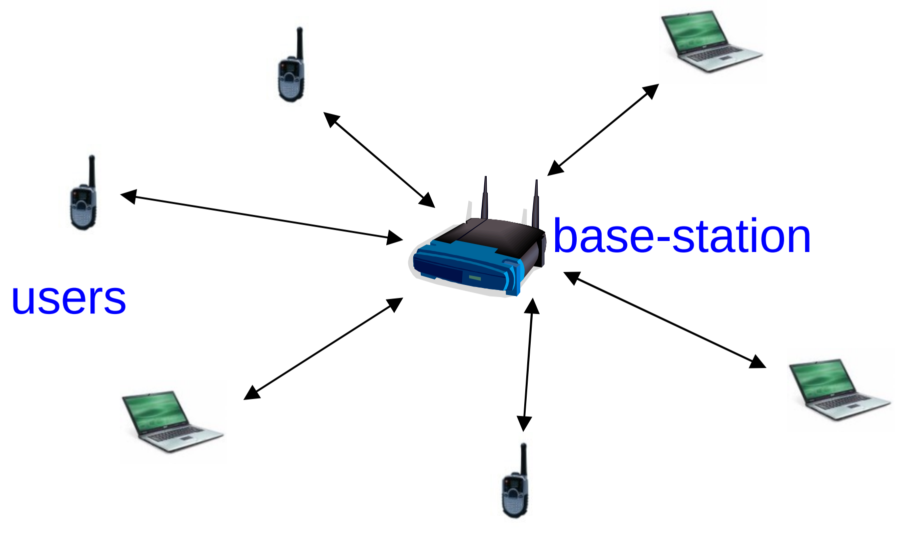
Outline

- What are mesh networks
- Applications of wireless mesh
- Quality-of-service
- Design and development of a TDMA mesh

Point to Multipoint

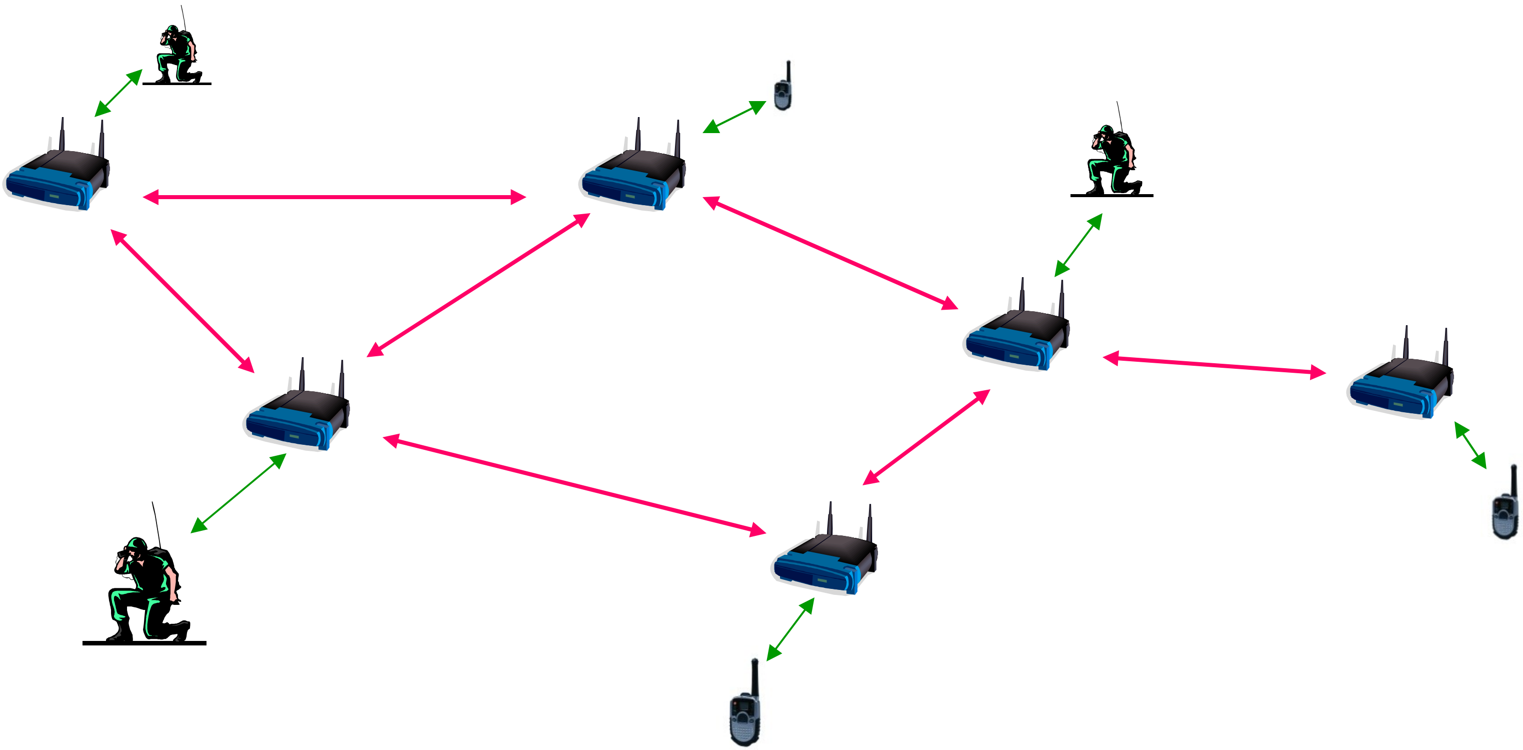
- WiFi
  - single base-station/access point
  - users associate with base-station



- Drawback: covers small area

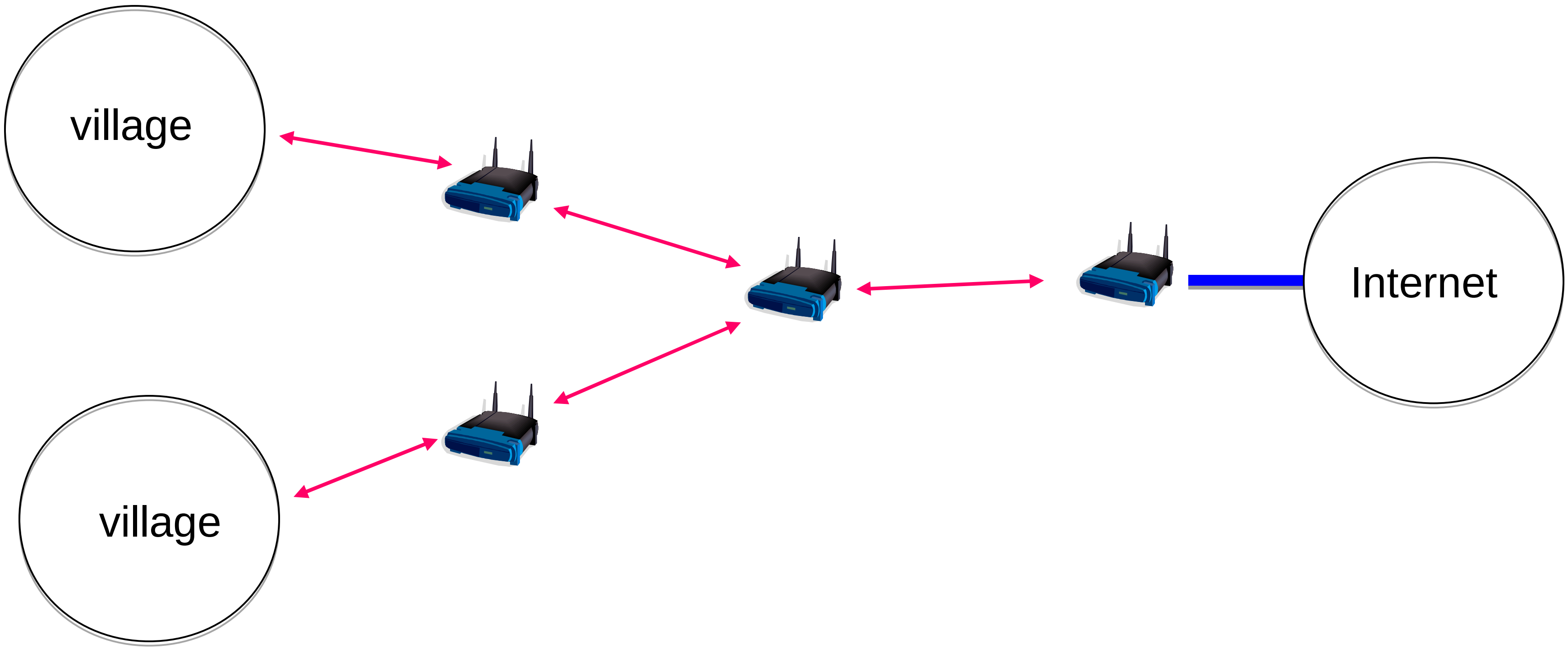
Wireless Mesh Networks

- Multi-hop wireless
- Large coverage area
- Unlike MANETs, base-stations are static (limited nomadic capability)



Applications of Mesh Networks

- Internet connectivity to areas lacking wired connectivity
  - rural areas, disadvantaged urban communities



Disaster Management

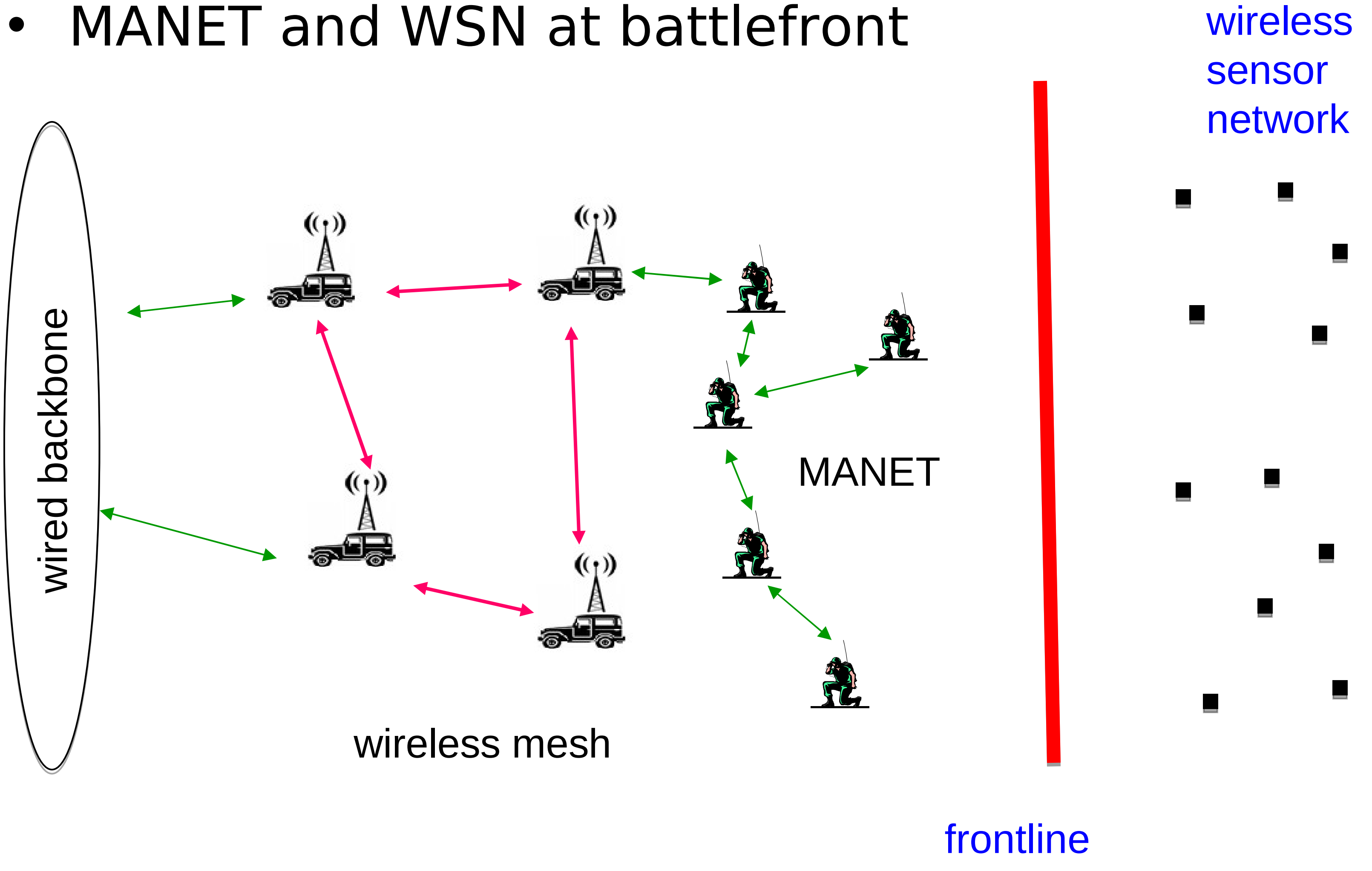
- Cyclones, tsunamis, earthquakes can destroy communication infrastructure

Tsunami devastation

(source: yenisafak.com.tr)

Military Battlefield

- Mesh connects frontline to wired backbone
- MANET and WSN at battlefront



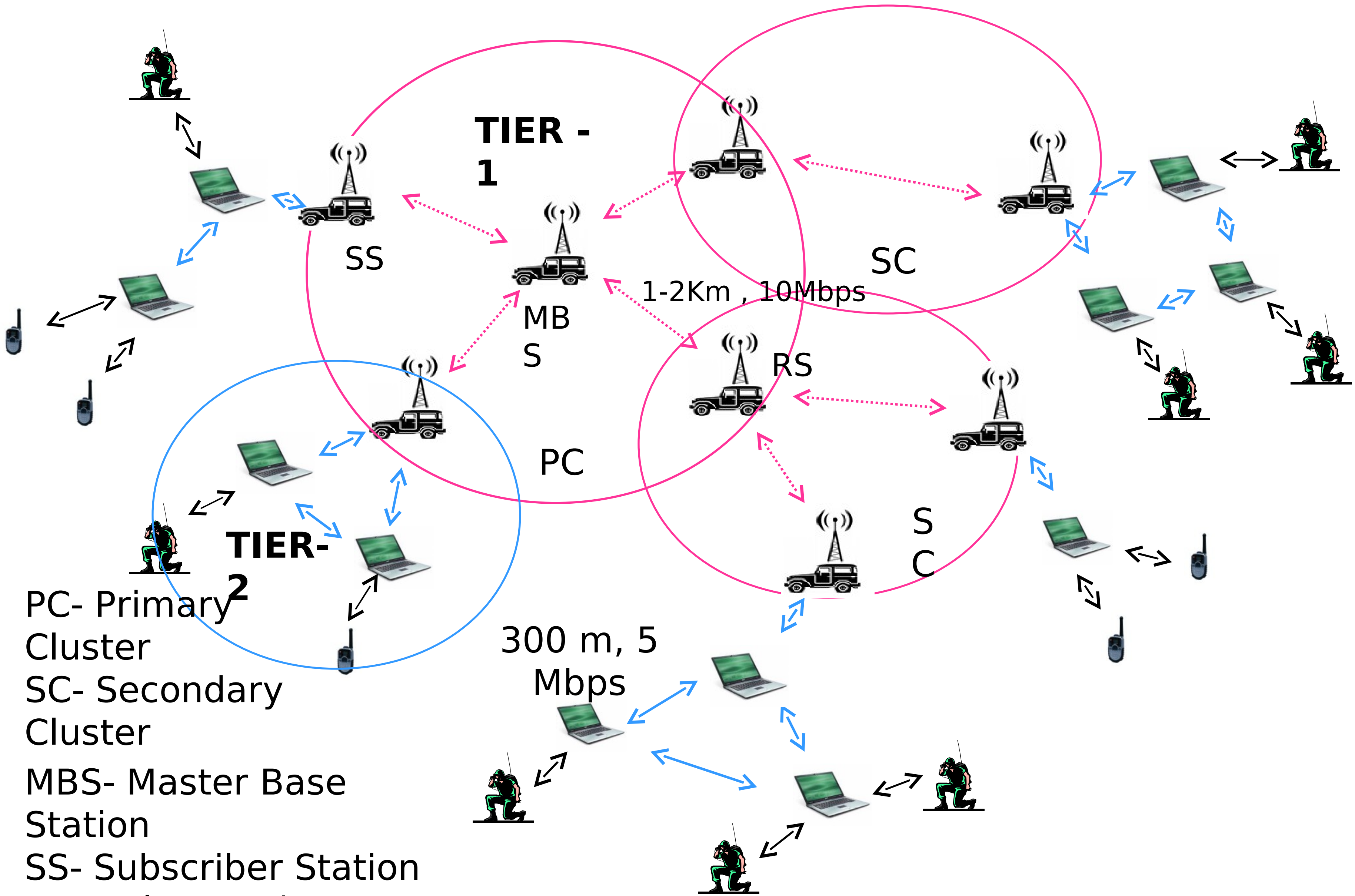
Application Requirements

- Long range (10km diameter)
- Quality-of-service
  - triple play (voice, video, data)
  - high bandwidth (several Mbps), low end-to-end delay (20ms)
- Rapid deployment (minutes)
  - disaster management, military
- Robustness to node failure

Ongoing DIT Project

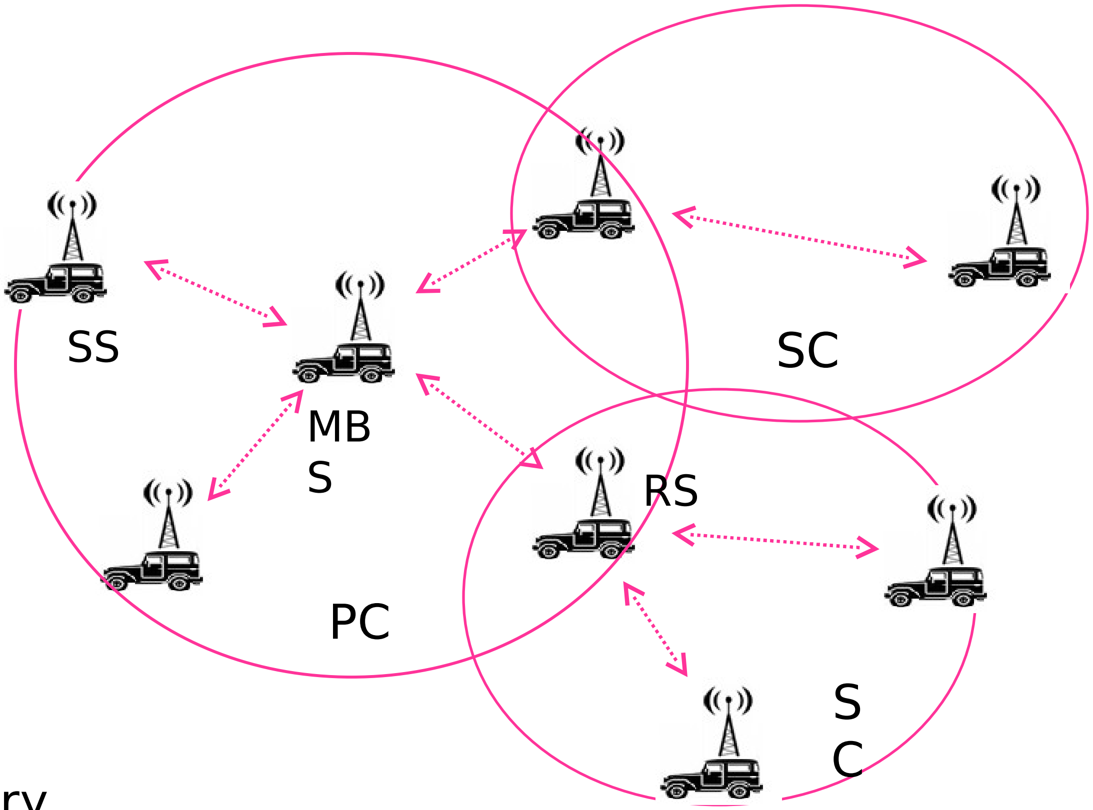
- Title: “Design and development of a rapidly deployable WiMAX-based mesh network”
- Investigators: Huzur Saran, Vinay Ribeiro, B. N. Jain, Kolin Paul (CSE dept, IIT Delhi)
- Focus on disaster management and military scenarios
- Build prototype mesh node

Two Tier Network Planned



PC- Primary Cluster
SC- Secondary Cluster
MBS- Master Base Station
SS- Subscriber Station
RS- Relay Station

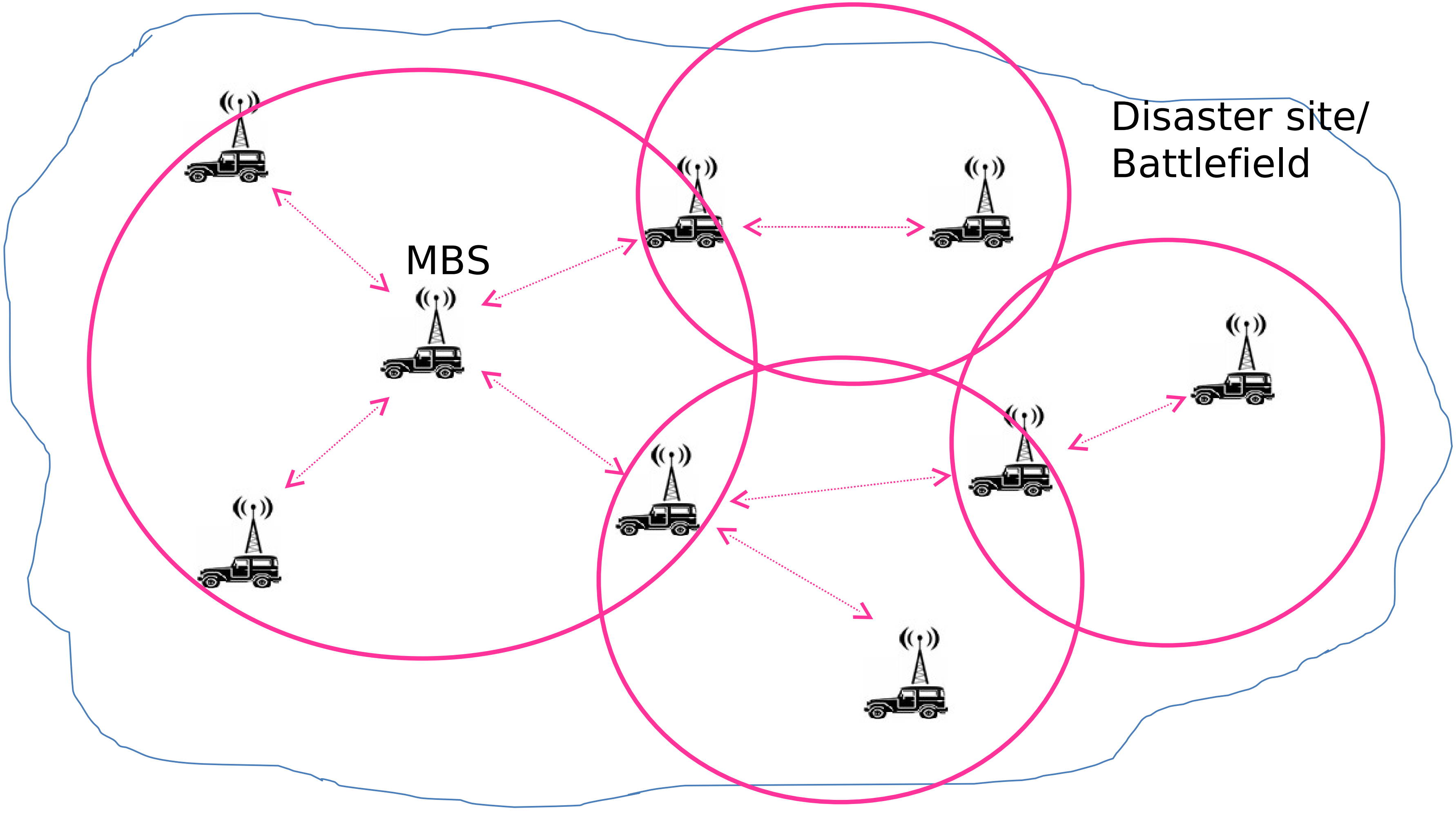
Tier-1 Topology



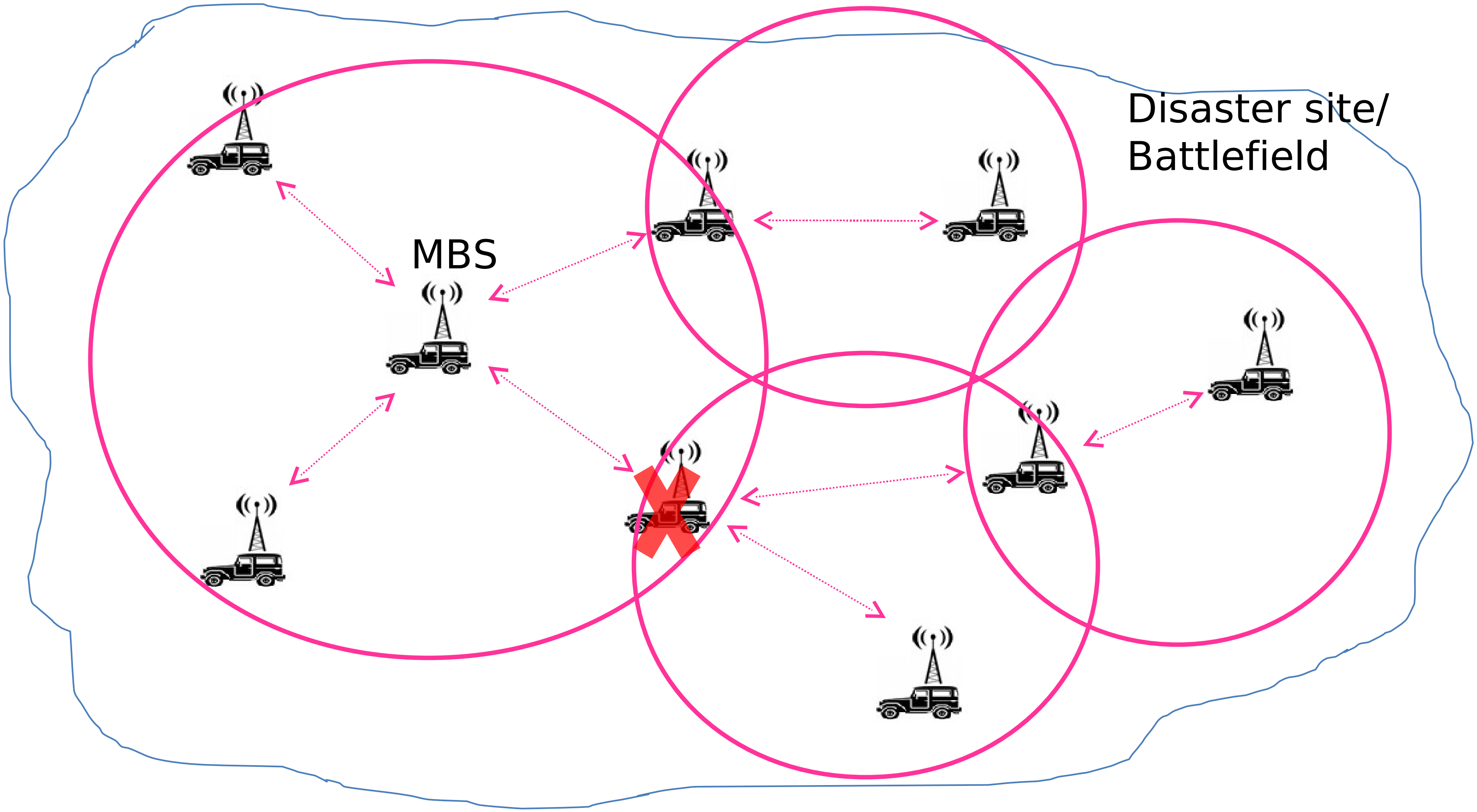
PC- Primary Cluster
SC- Secondary Cluster

MBS- Master Base Station
SS- Subscriber Station
RS- Relay Station

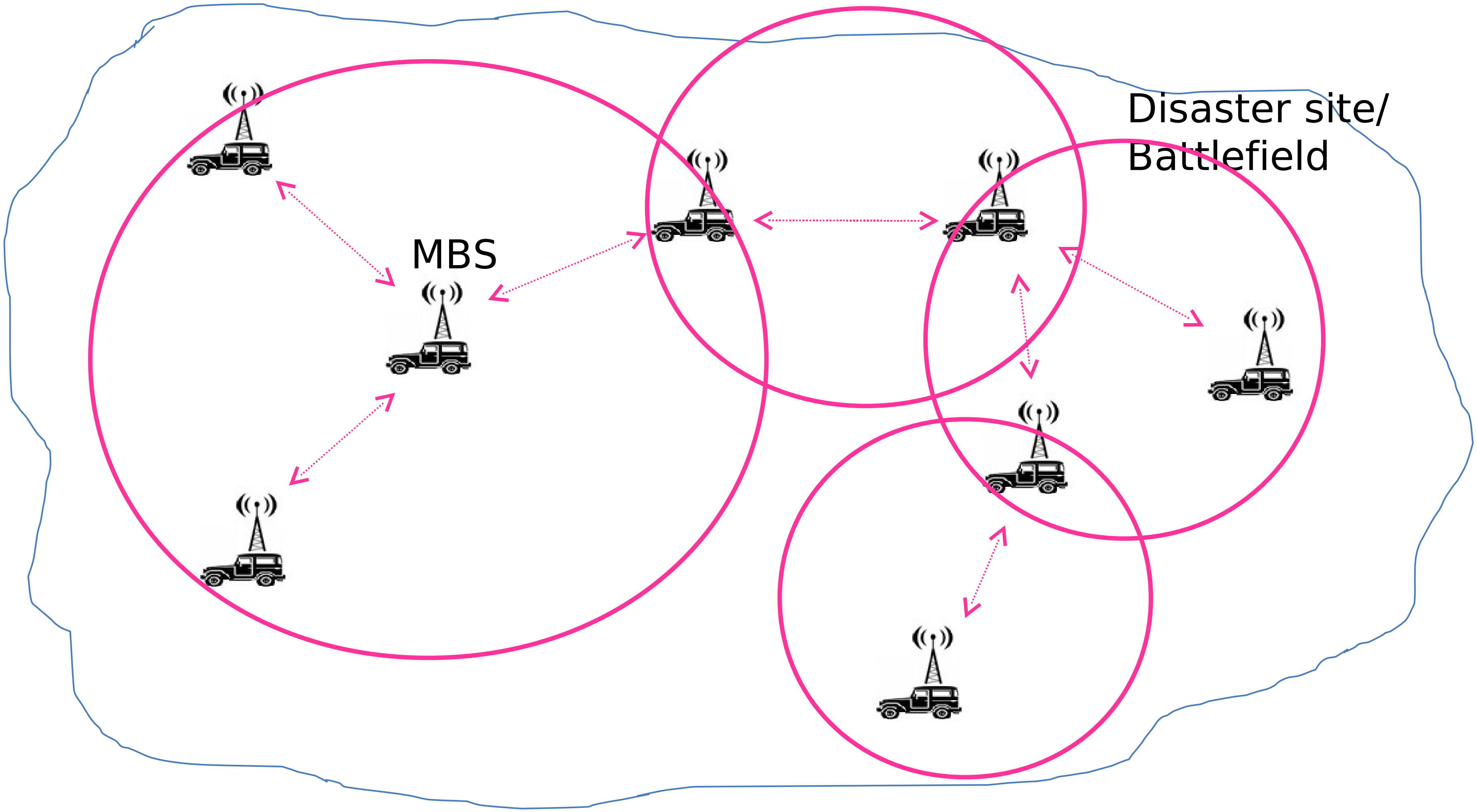
How Rapidly-Deployable and Self-configurable?



How Robust to Node Failure?

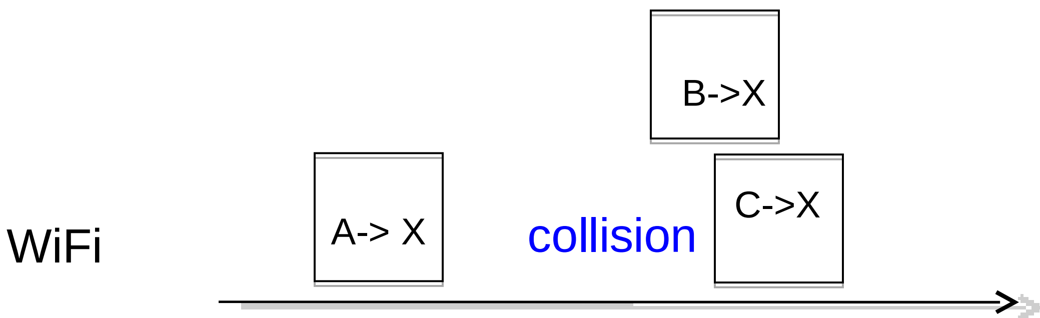


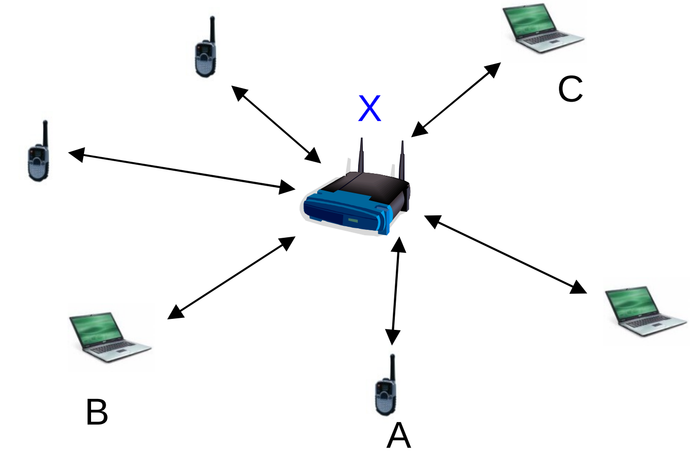
How Robust to Node Failure?

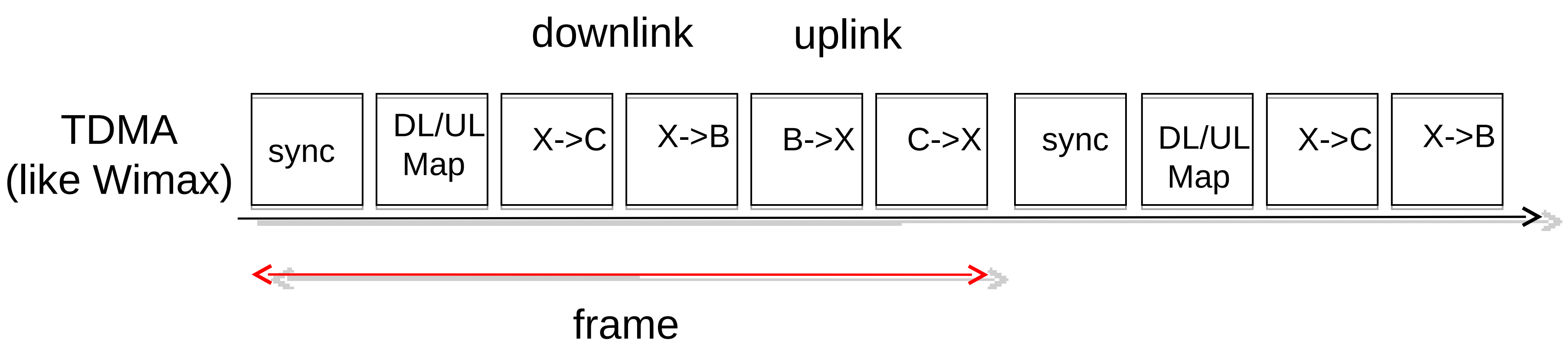


Quality of Service

- Use TDMA, as in WiMAX

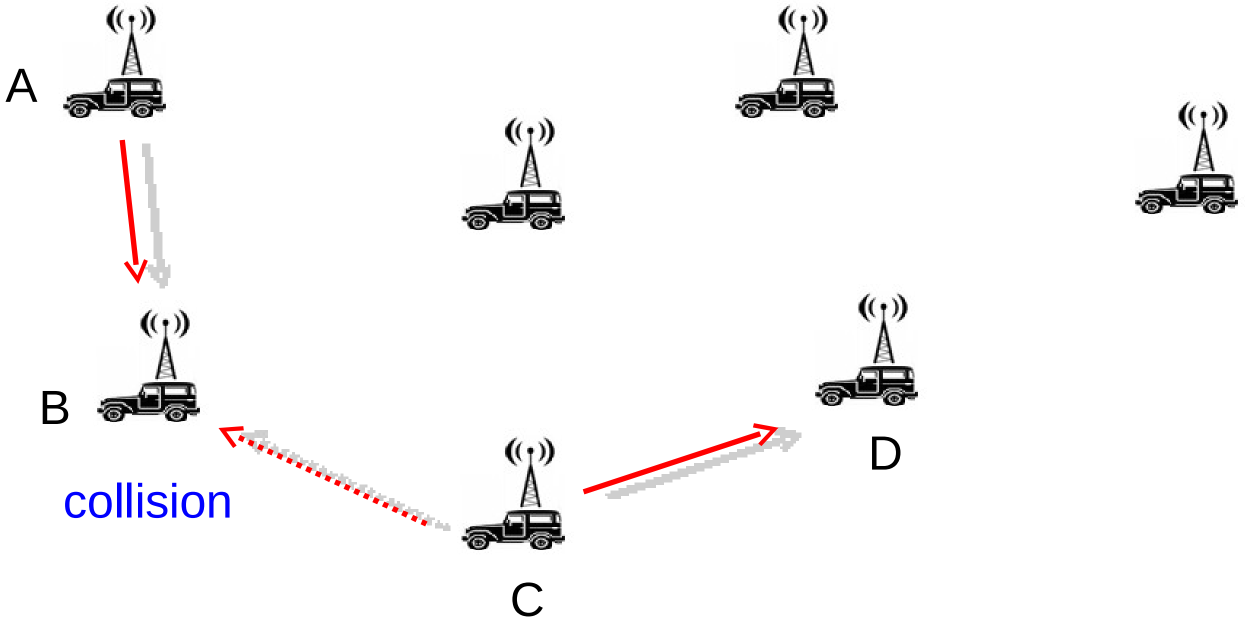






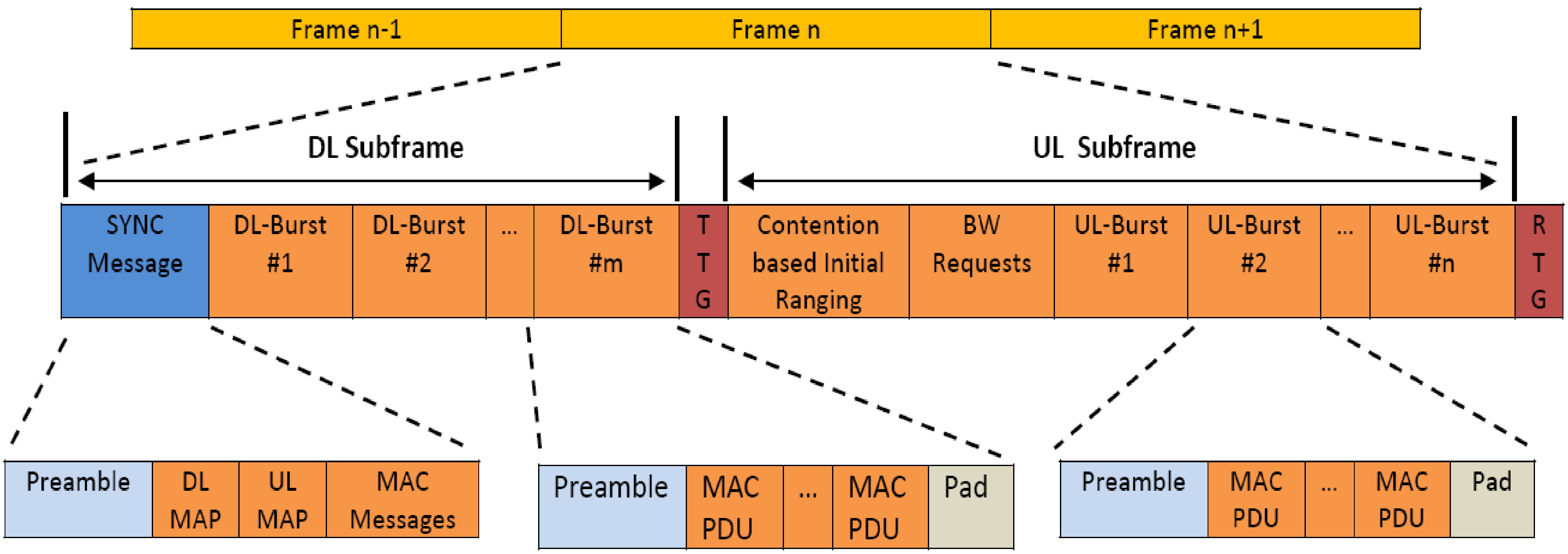
Scheduling in Mesh is Non-Trivial

- Interference, hidden terminal problems
- joint scheduling and routing

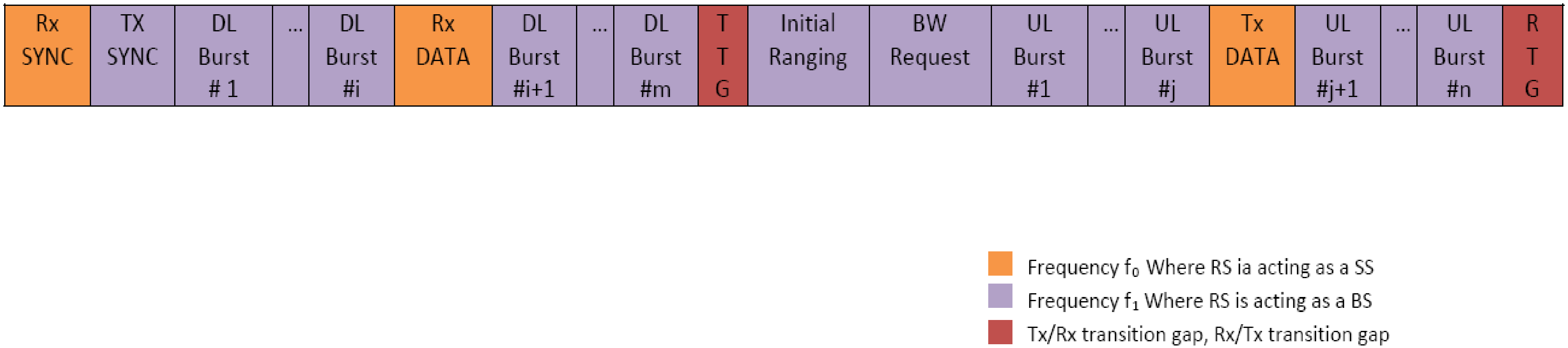


- need spatio-temporal scheduling

Frame Structure of MBS



Frame Structure of RS



Relay uses different frequency channel in its own cluster

Frame Structure of SS

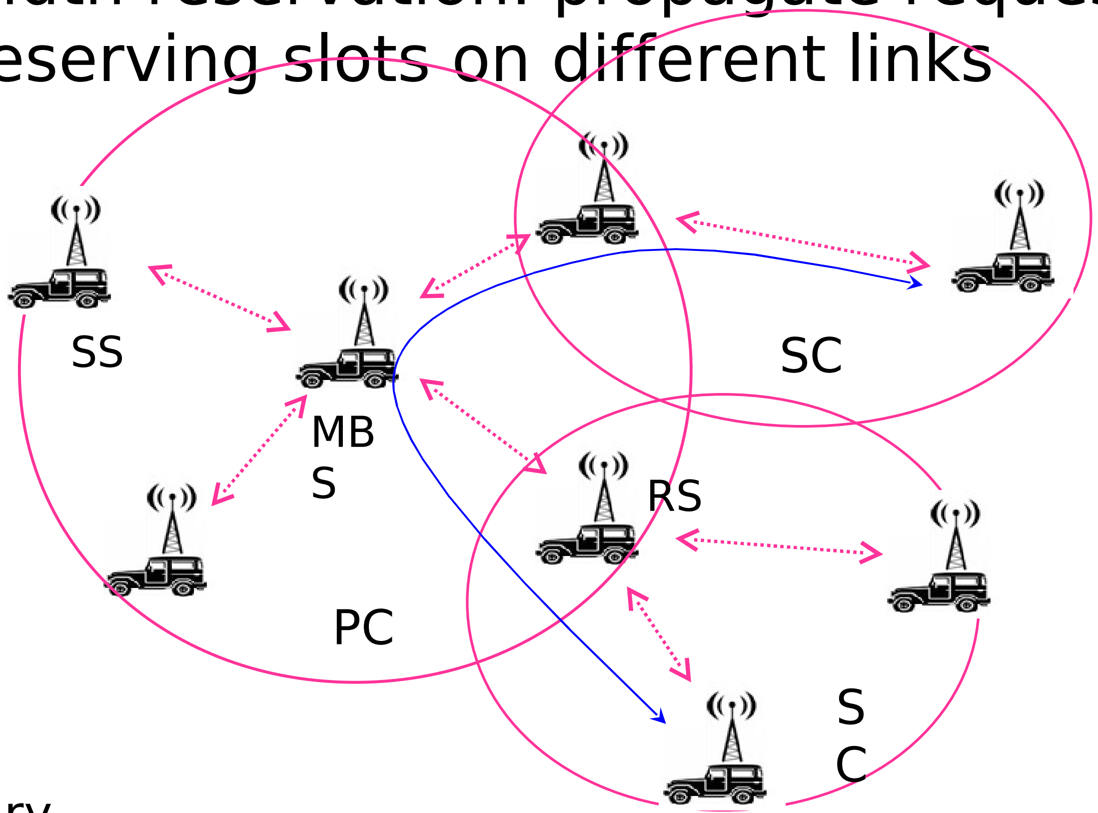
Receive SYN from BS	Transmit SYN (Different frequency)	...	Receive Data from BS (DL Slot)	...	Initial Ranging (Different frequency)	BW Request	...	Transmit DATA to BS (UL slot)	...

Sent in each ith frame where i is a configurable parameter.

- SS can act as a relay for other nodes
- each cluster uses different frequency band
- when SS not communicating with MBS, switch to own frequency and transmit SYN

Scheduling and Routing

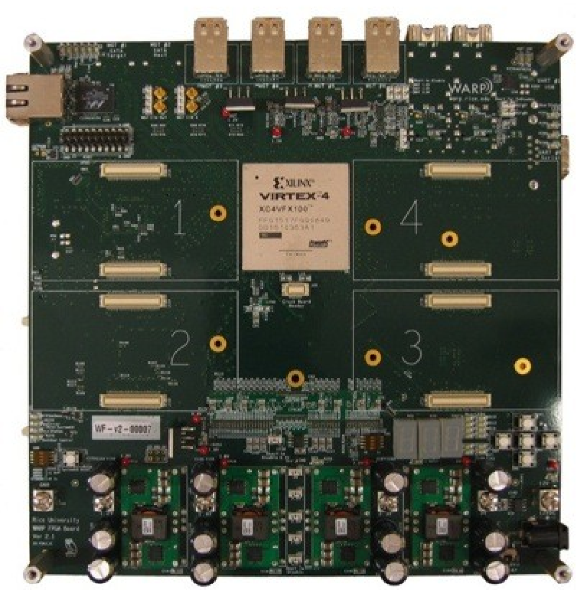
- Tree structure: only one routing path between pair of nodes
- bandwidth reservation: propagate request over tree, reserving slots on different links



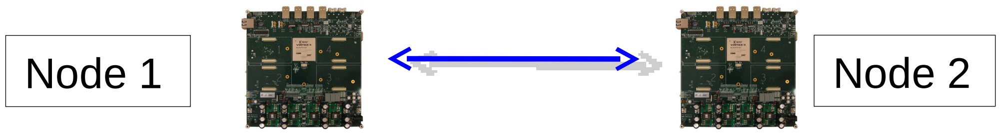
PC- Primary Cluster
SC- Secondary Cluster

Hardware Platforms

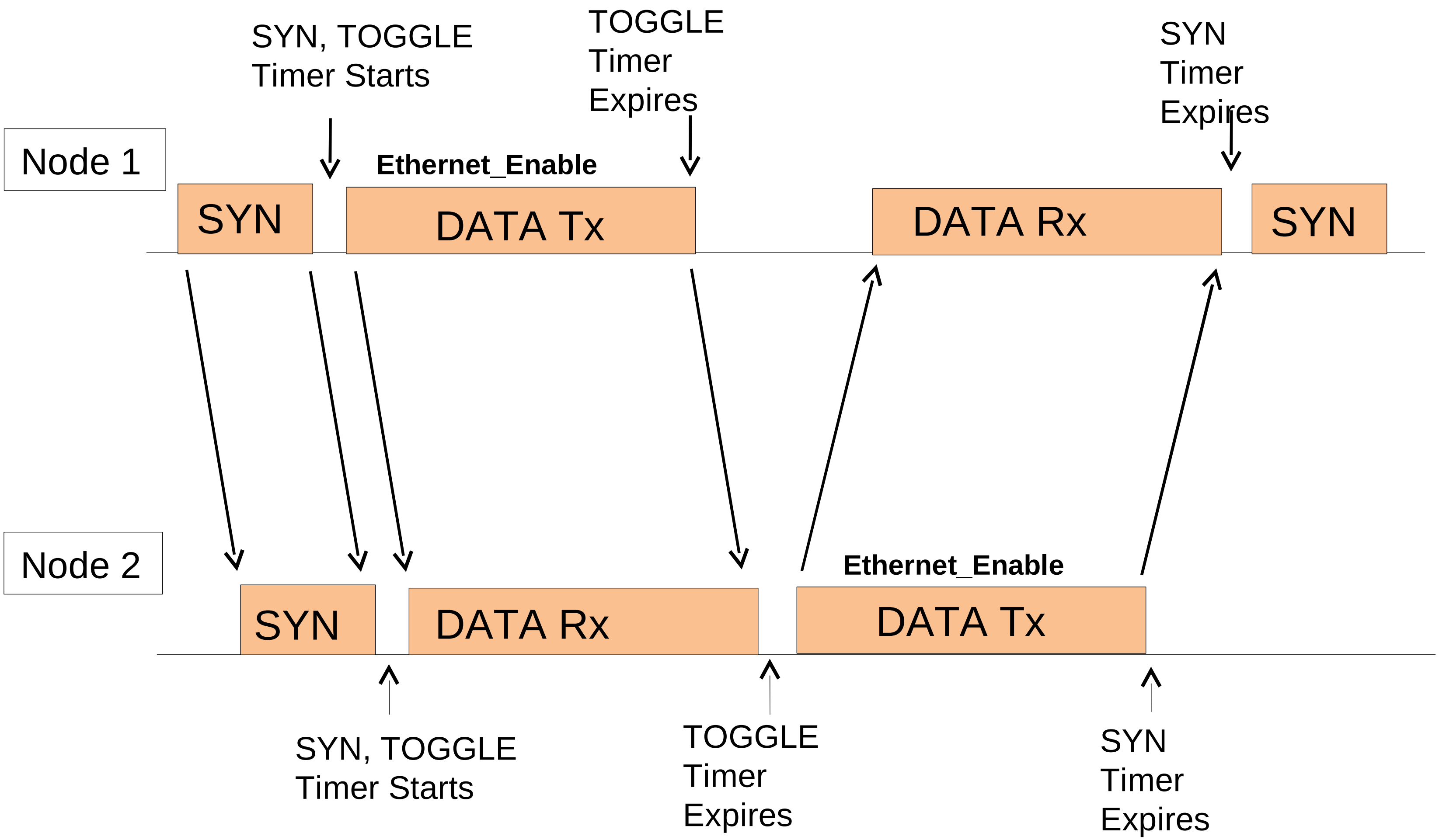
- Wireless open Access Research Platform (WARP)
  - tier-1 mesh node, FPGA-based, RF daughterboards (WiFi chipsets)
  - standalone board, 2.4GHz ISM band
- Runcom technologies WiMesh node
  - tier-2. PCMCIA cards, WiMAX self-configurable, multihop,



Two Node TDD

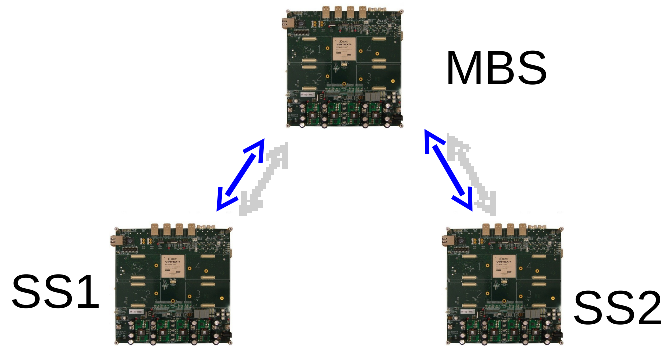


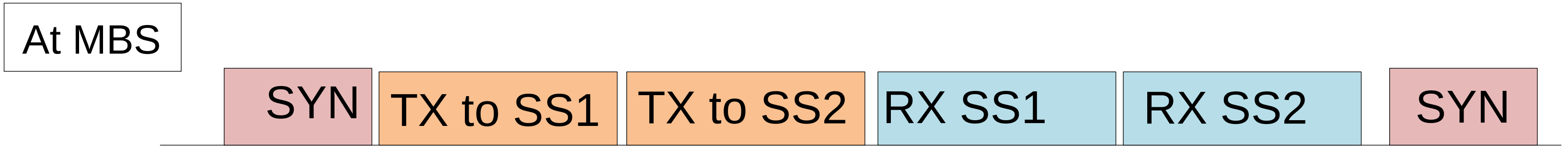
Node 1
Node 2



SYN, TOGGLE
Timer Starts
TOGGLE
Timer
Expires
SYN
Timer
Expires
Node 1
Ethernet_Enable
SYN
DATA Tx
DATA Rx
SYN
Node 2
Ethernet_Enable
SYN
DATA Rx
DATA Tx
SYN, TOGGLE
Timer Starts
TOGGLE
Timer
Expires
SYN
Timer
Expires

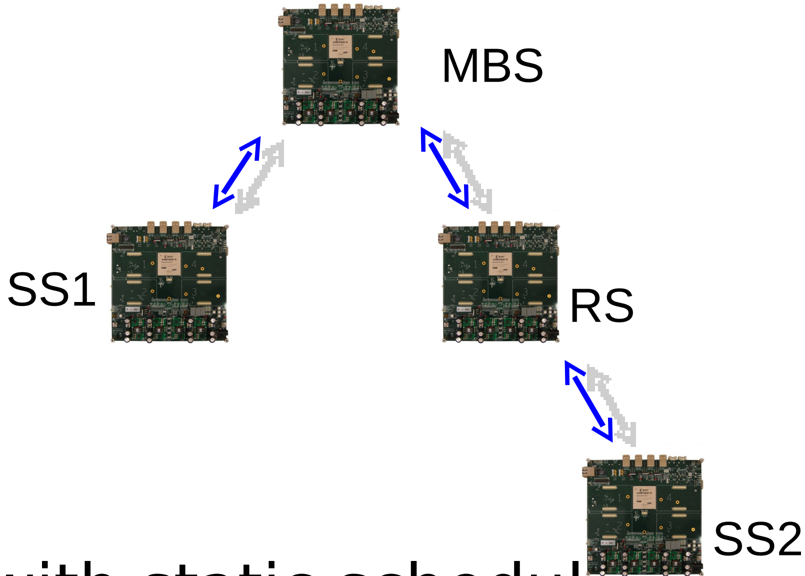
Three Node TDMA





- SS1 → MBS → SS2 throughput (iperf UDP): 8 Mbps
- Fixed schedule, no application specific QoS yet
- PHY: SISO, 10MHz chl, OFDM, 2.4GHz band, QAM-16
- MAC: frame length 4.8ms, slot duration 1ms

Four Node Mesh



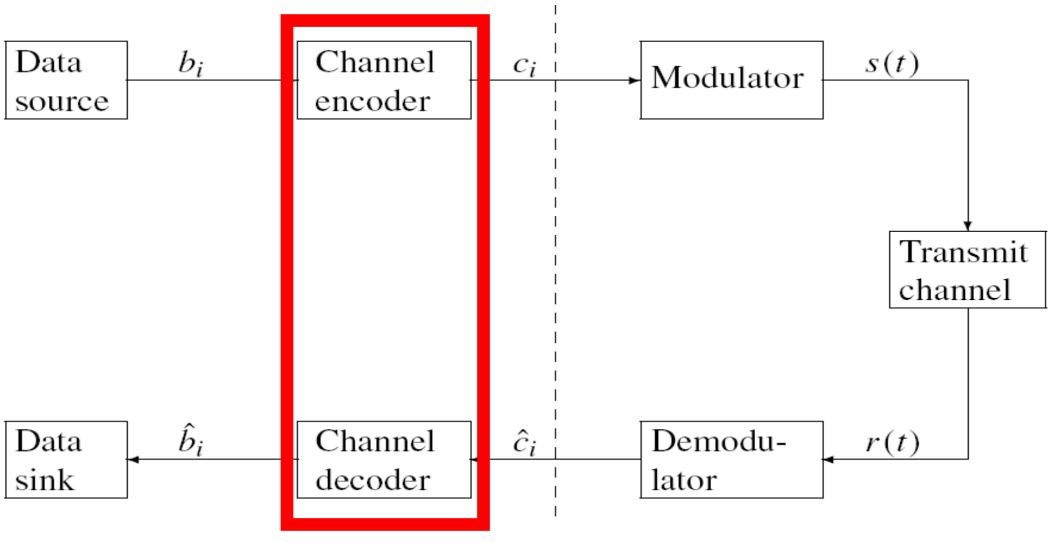
- Implemented with static scheduling
- Frame size: 7ms, slot size 1ms
- Experimentation ongoing

Achieving Long-Range

- directional antennas (not good for rapid deployment)
- Increase transmit power
- increase antenna height
- improve coding, use MIMO
- use lower center frequency

Reducing Packet Loss

- Type-1 Hybrid ARQ
  - If no. of errors is within the error correcting capability of the FEC code then decoded message saved
  - Else received message is discarded and retransmission requested



- Result: Packet loss decreased by 4x for CSMA MAC, SISO, LOS
- FEC used: convolutional code used in 802.11a

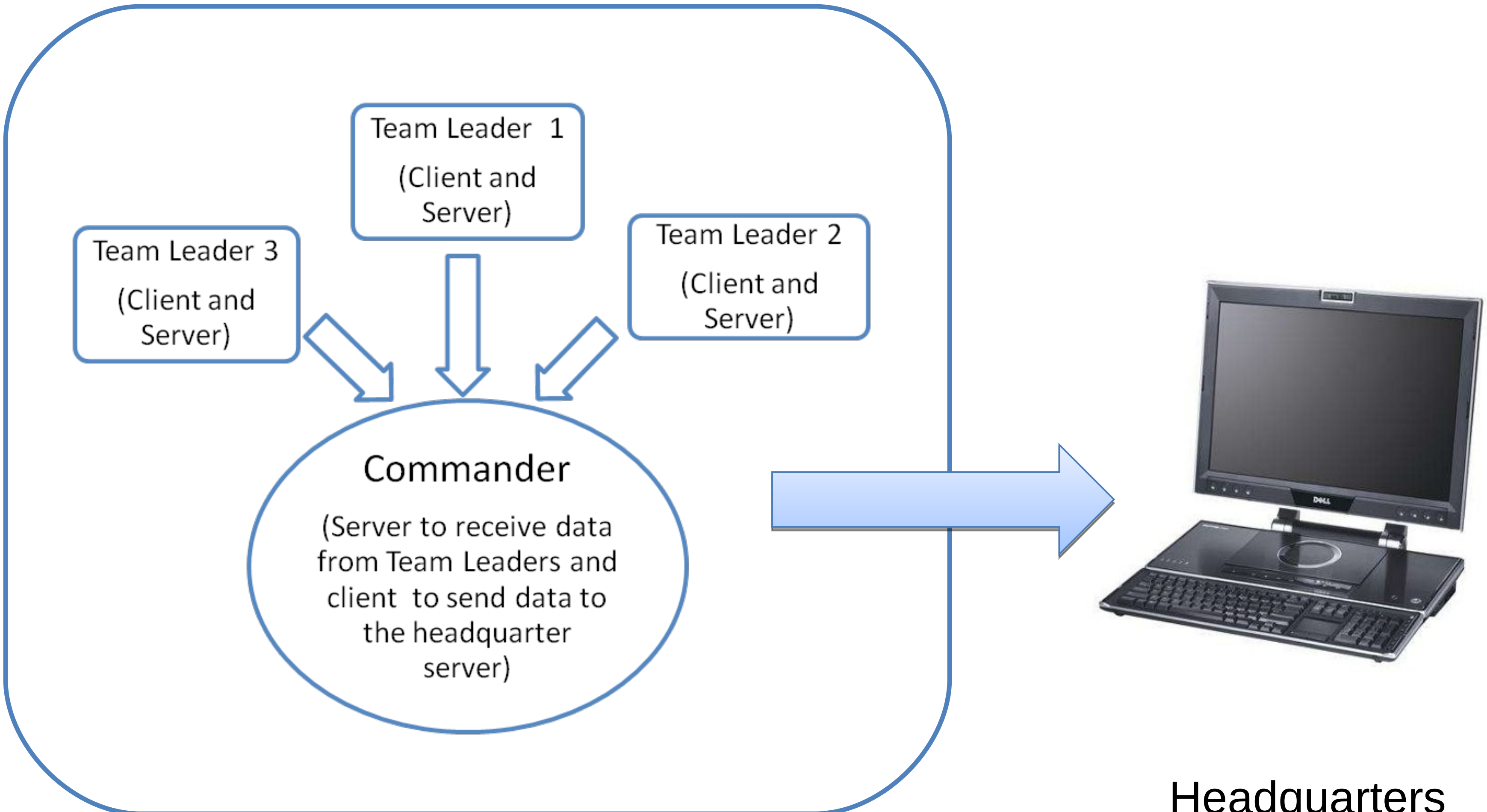
Runcom WiMesh Experiments

- Preliminary results (may improve with upgraded firmware)

- Two node experiment, transmit power: 15dBm
- Outdoor NLOS: range 53m, 6 Mbps data rate
- Outdoor LOS: range 120m, video streaming
- uses two bands 2.3GHz and 2.7GHz
- two transceivers (uplink/downlink simultaneously)
- Future: Handoff experiments, directional antennas

Disaster Management Applications

- Android based, hands-free, voice-based activation



Headquarters (Web Server)

Disaster Site (Mobile Applications)

Conclusions

- TDMA wireless meshes can provide QoS over large spatial area, all-wireless
- Design of a rapidly deployable mesh for disaster management
  - two tier network
- Platform choice WARP, Runcom WiMesh
- 4-node tier-1 network developed, applications on Android
- Future: implementation of dynamic node joining, QoS/bandwidth reservation