Mobile Ad hoc Networks COE 549
Ad hoc Network Overview

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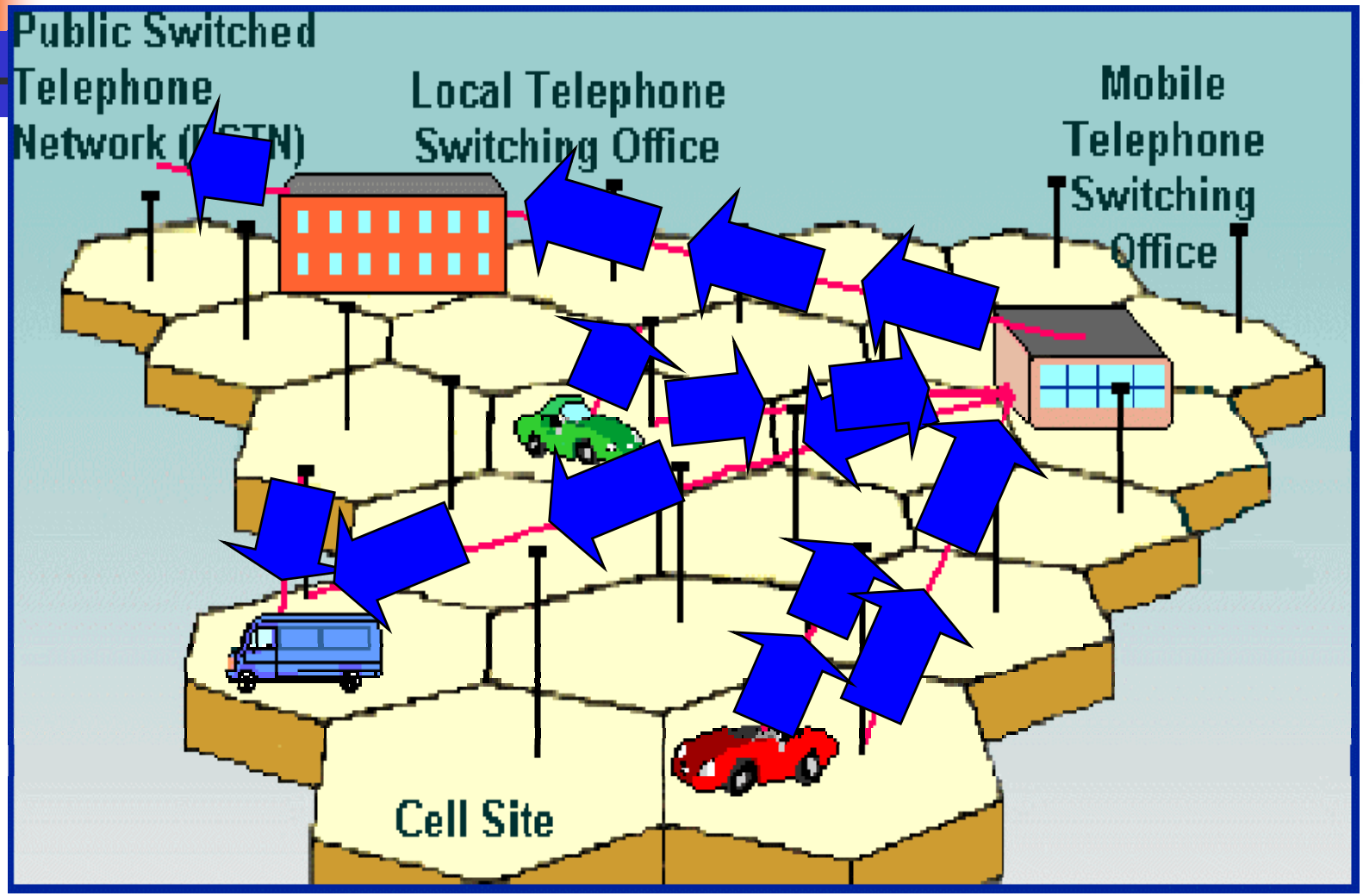
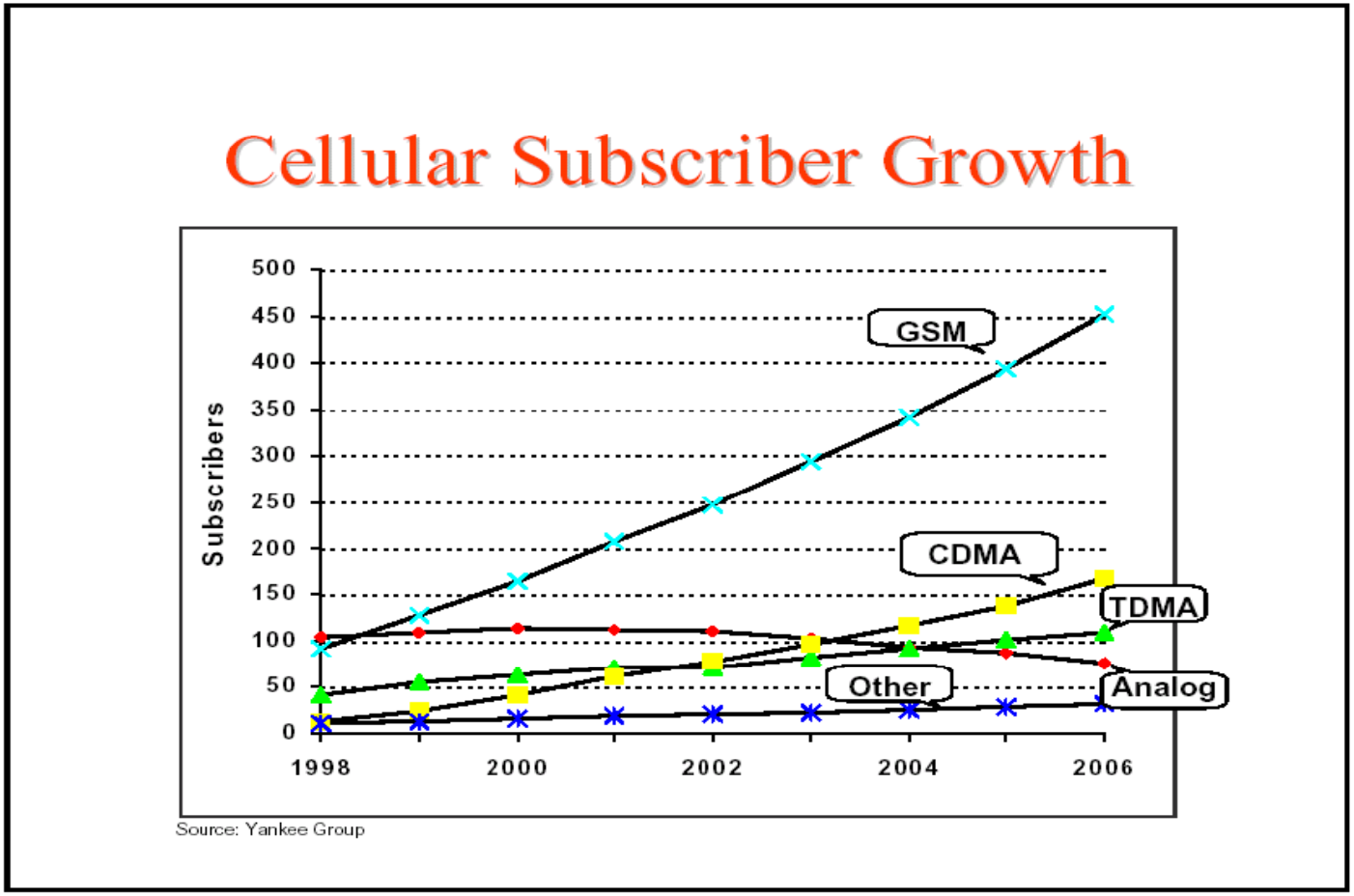
Overview

- Introduction
- Comparison with the cellular topology
- Applications (military and civilian)
- Deployment
- Localization
- Topology control
- Mobility models
- Capacity
- Power control

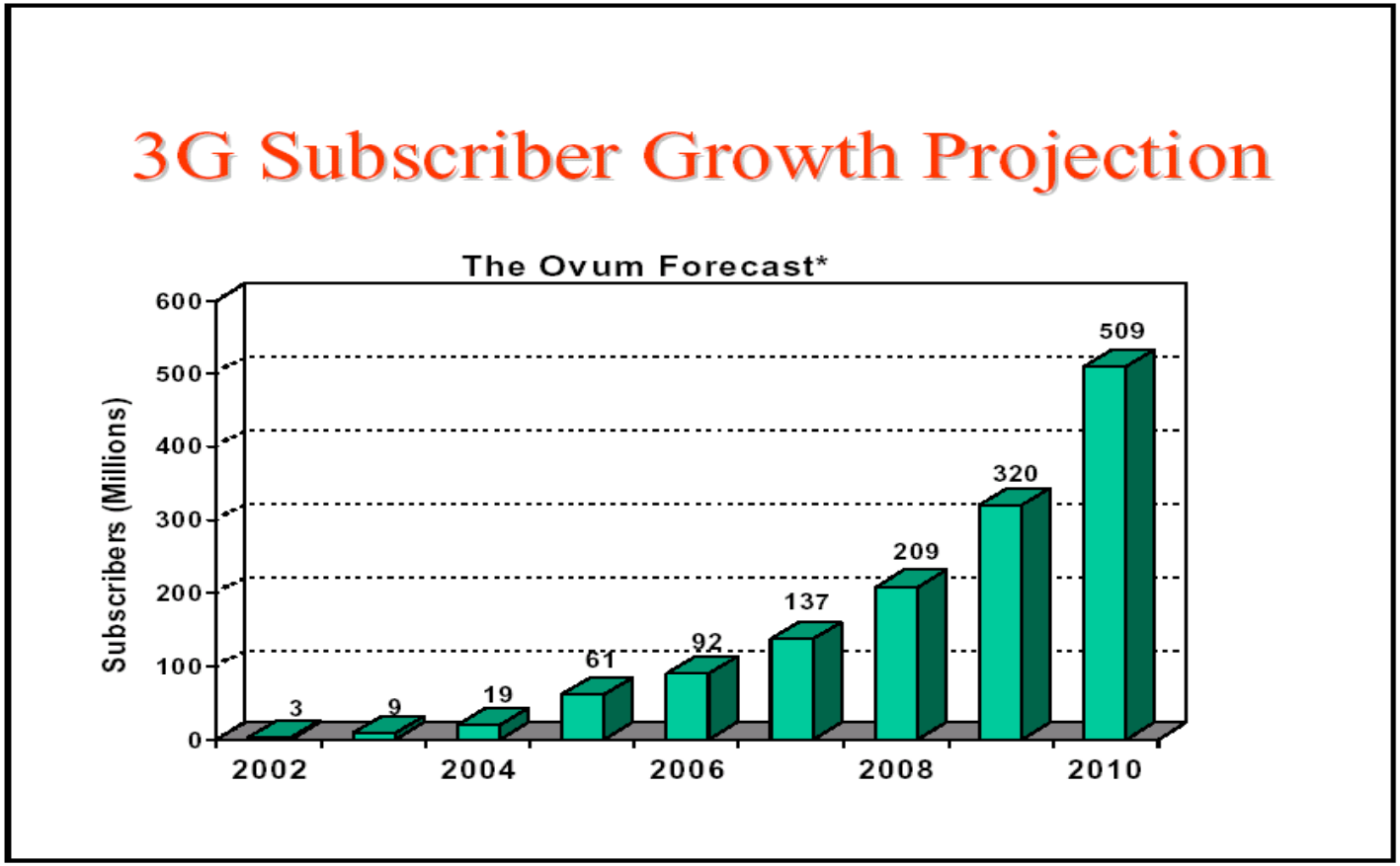
Introduction- Conventional Wireless Communications



Cellular Subscribers

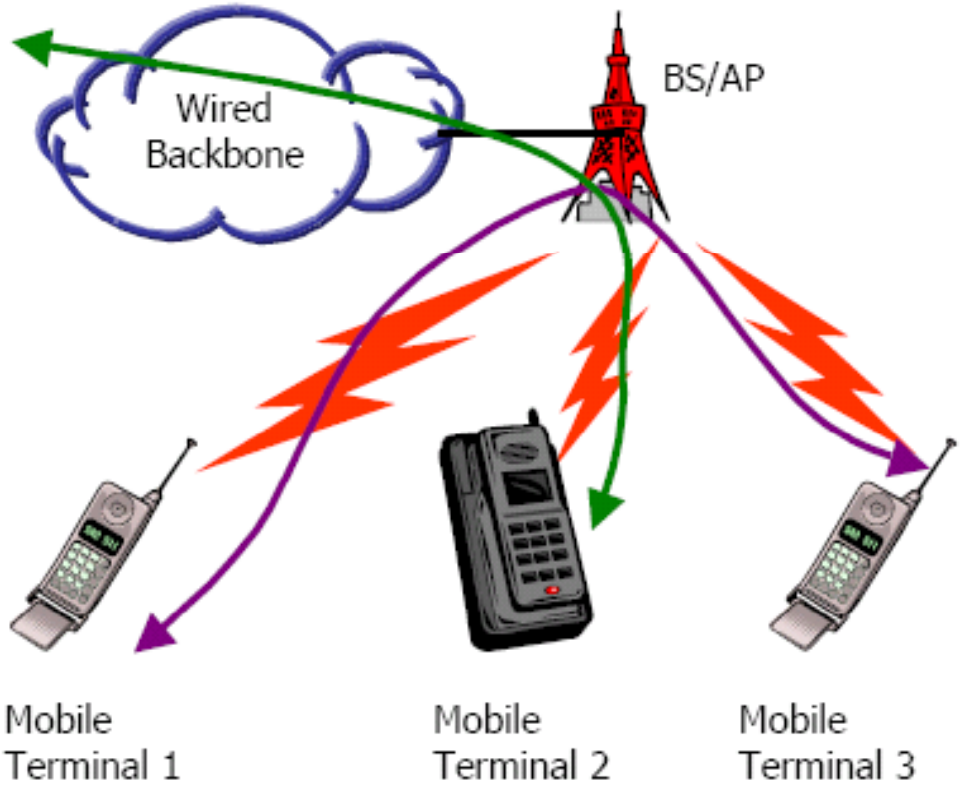


Cellular Subscribers..



Introduction

1. Infrastructure Network Topology:
   - There is fixed (wired) infrastructure that supports communication between MT and fixed terminals
   - It is often designed for large coverage areas and multiple BSs or APs
   - BSs/APs serves as the hub of the network
   - Any communication from one MT to another has to be sent through the BS/AP
   - The hub station usually controls the MT and monitors what each station is transmitting

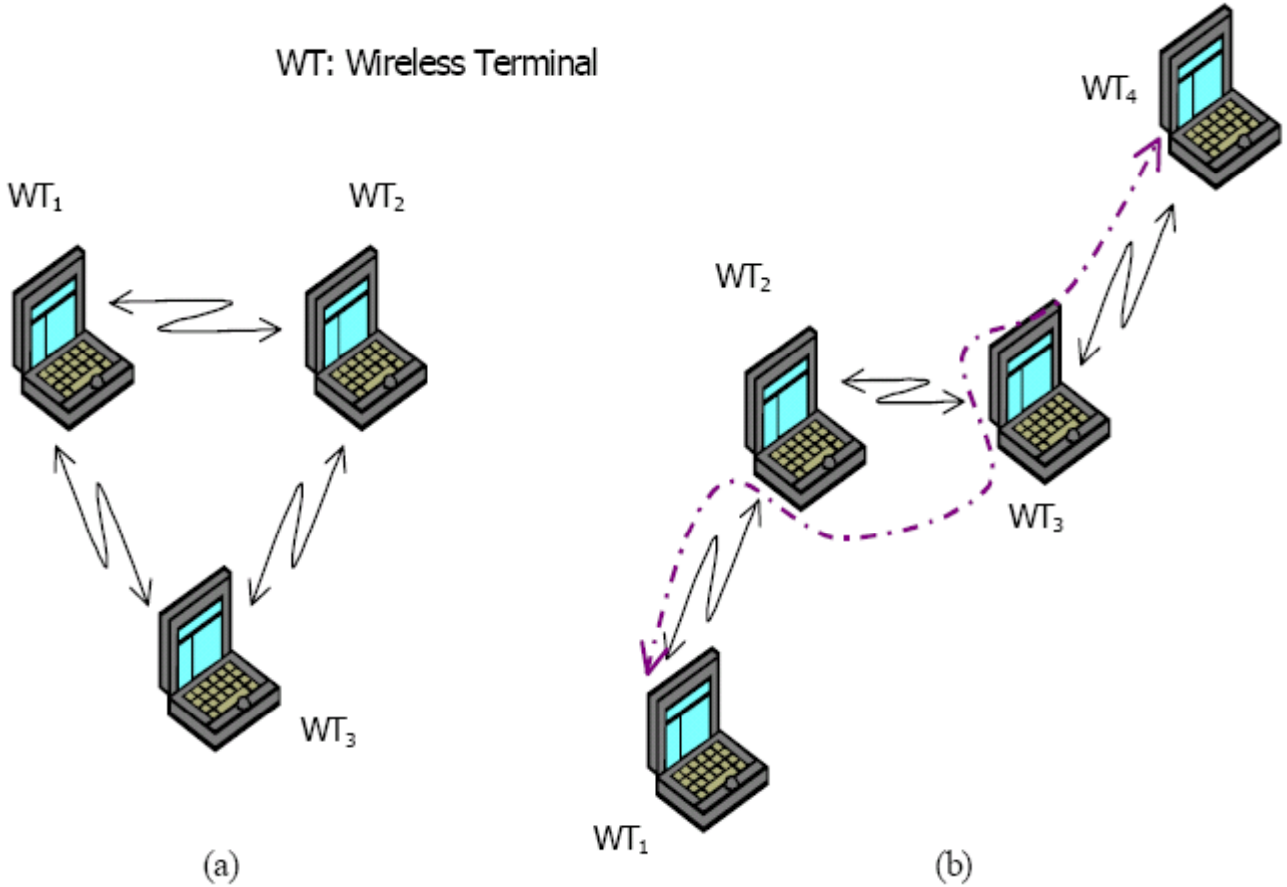


Basic operation of an infrastructure network topology

Introduction..

2. Infrastructure-less Network Topology:

- Can operate without the need for a fixed infrastructure
- Best suited for conference meetings, lectures, crowd control, search and rescue, disaster recovery, on-the-fly conferencing applications, and automated battlefields. Typically such applications do not have infrastructure or central administration available
- Users have to cooperate in carrying messages through the network
- Ad hoc Network = multihop network



Ad-hoc networking (a) Single-hop peer-to-peer topology (b) Multi-hop ad-hoc networking topology

Comparison of Ad hoc and Infrastructure Network Topologies

- Scalability:
  - To scale up a wireless infrastructure network, the number of BSs or APs is increased to expand the coverage area or to increase the capacity
  - In ad hoc networks, it depends on the routing protocol
- Flexibility:
  - Operation of infrastructure networks is very expensive
  - Ad hoc network is very flexible
- Controllability:
  - Infrastructure network centrally controlled and synchronized
  - In ad hoc networks there is no centralized administration
  - Therefore, infrastructure network is more controllable than ad hoc

Comparison of Ad hoc and Infrastructure Network Topologies..

- Routing Complexity:
  - In ad hoc network, each node must act a router. There is a need for routing algorithms that directs the info to the appropriate next hop
  - This problem does not exist in infrastructure network
- Coverage:
  - In WLANs, coverage of the network is an issue of concern
  - The max distance between two MTs is the max transmission range of MTs
  - In infrastructure network, two MTs communicate through BS/AP
  - The max distance is twice range of the coverage of a single wireless modem

Comparison of Ad hoc and Infrastructure Network Topologies..

- Reliability:
  - Ad hoc network is resistance to failure
  - Infrastructure network are "single failure point network. If the AP/BS fails, the entire communication network is destroyed
- Store and Forward Delay and Media Efficiency:
  - In infrastructure topology, data is transmitted twice. Once from the source to the BS/AP and once from BS/AP to the destination
  - The BS/AP should store the message and forward it later. This adds to the delay encountered by the data packets
  - Ad hoc may have several transmissions and several store and forward delays

Why Ad hoc Networks?

- No infrastructure needed
- Can be deployed quickly, where there is no wireless communication infrastructure present
- Can act as an extension to existing networks → enhances coverage
- Cost-effective – cellular spectrum costs $XX billion
- Adaptive computing and self-configuring
- Support for heterogeneous computational devices and OSs

Ad hoc Constraints

- Dynamic topologies
- Bandwidth-constrained
- Constraints on Tx power
- Infrastructure-less property, no central coordinators → hidden terminal, exposed terminal
- No QoS preservation
- Load balancing
- Energy-constrained operation
- Limited physical security

History

1. Research started in the 70's
   - ARPA Project initiated in December '72 at Stanford University meeting
2. Interest cooled off in the 80's.
3. Renewed interest in the 90's, still going strong.
   - Wireless communications are very popular.
   - Today's powerful technology makes ad hoc networks feasible and practical

➢Different names for the same thing:

- Packet radio networks (70's), multihop wireless networks (80's), wireless ad hoc networks (90's)

Mobility Models

Cellular Network

- The area is divided into independent cells
- The exact position of the node is irrelevant
- Mobility models used for simulating handover

Ad hoc Networks

- There are not necessarily fixed stations
- Network routes are created dynamically
- Dynamic network topology
- The level of mobility determines the dynamic of the network topology
- Examples: random walk, random waypoint, random direction

Structured vs Randomized deployment

- The randomized deployment approach is appealing for futuristic applications of a large scale
- Many MTs are likely to be deployed in a structured manner
- In both cases, the cost and availability of equipment will often be a significant constraint

Capacity of the network

Why capacity?

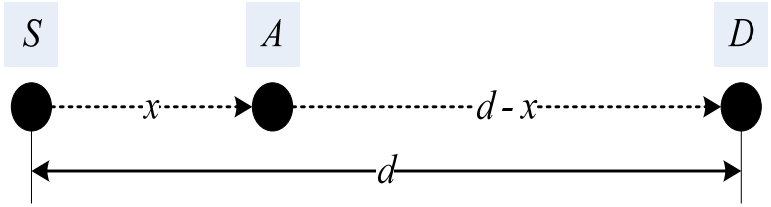
- If we know the theoretical limits, we can compare them with the performance of protocols we design and know how much we could improve
- If we know how the theoretical limits are achieved, we can improve our protocols
- Unfortunately, we still do not have any good answers

Topology Control

Are many small hops better than a big one?

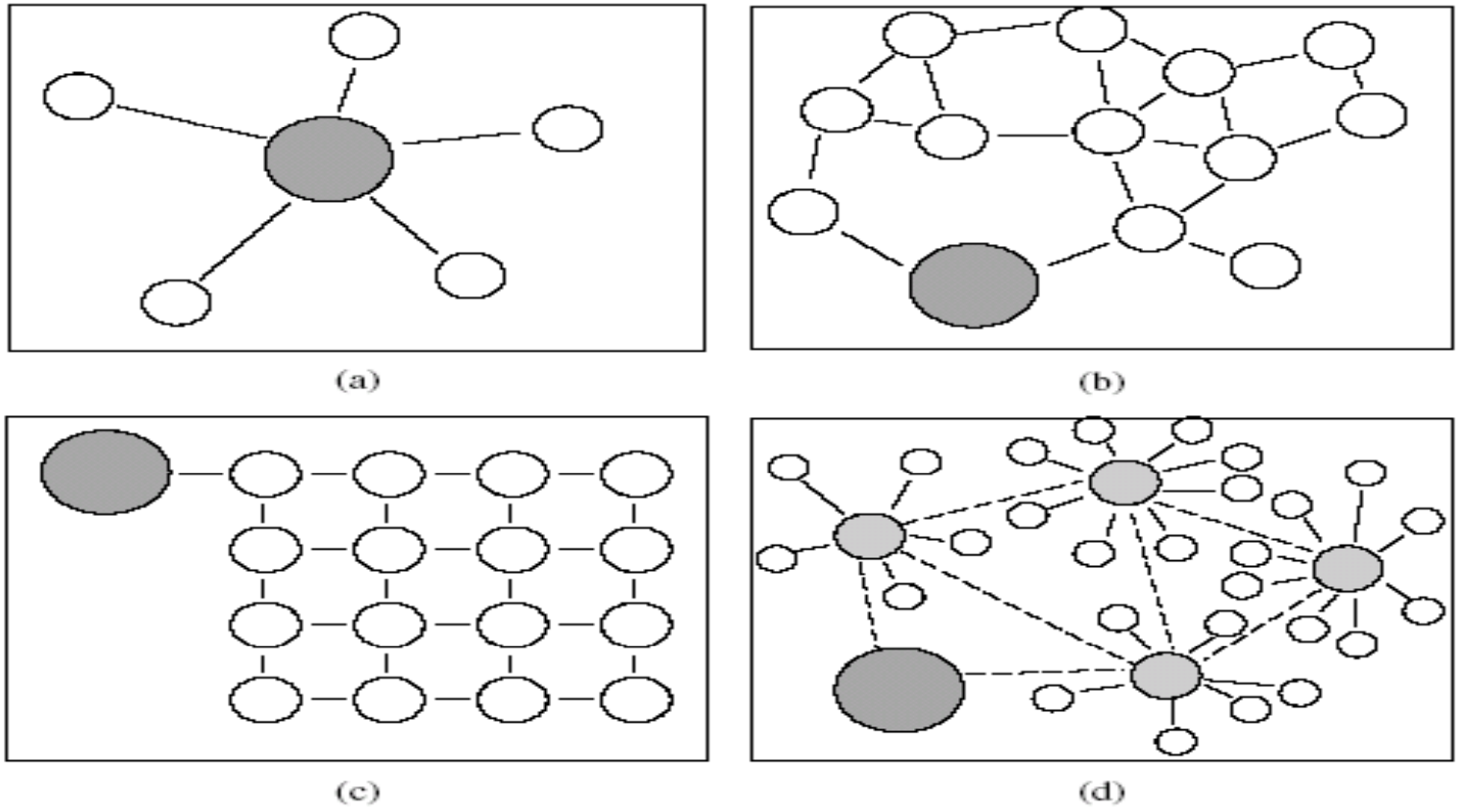
Power equation in ad hoc: $u(d) = ad^{\alpha} + c$

- Let us assume that the source S can reach the destination D directly. Let us further assume that there is a middle node between the source and the destination. Let |SA| = x and |SD| = d as in the below Figure



- If $d > (c/(a(1-2^{1-\alpha})))^{1/\alpha}$, then there is an intermediate node A between the source and destination such that the retransmission of the packet through A will save the energy. Moreover, the greatest saving is achieved when A in the middle of SD

Network Topology..



Different deployment topologies: (a) a star-connected single-hop topology, (b) flat multi-hop mesh, (c) structured grid, and (d) two-tier hierarchical cluster topology

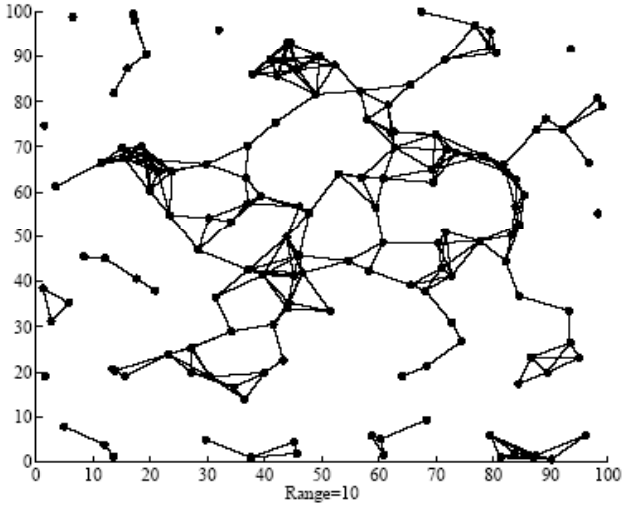
Localization

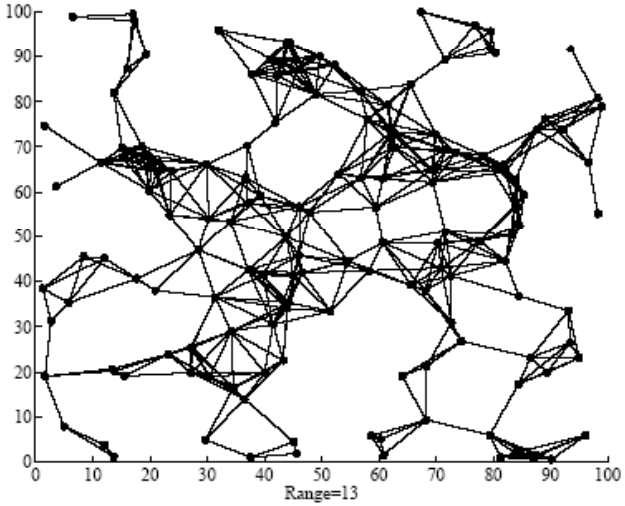
- Each individual node observation can be characterized essentially as a tuple of the form <S, T, M>, where S is the spatial location of the measurement, T the time of the measurement, and M the measurement itself. The location needed for the following reasons:

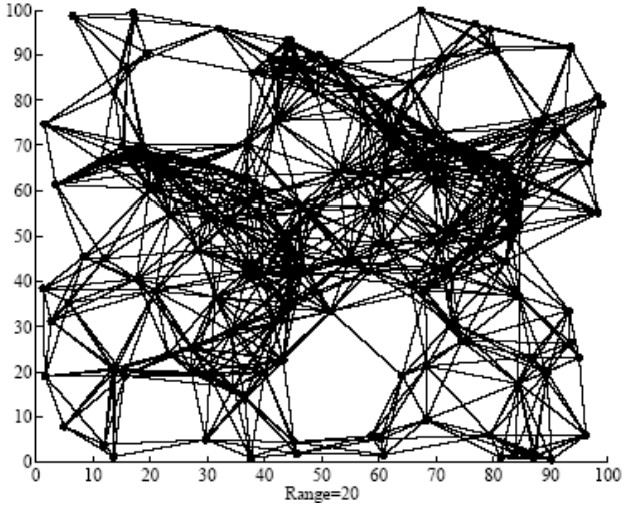
1. To provide location stamps
2. To locate and track point objects
3. To monitor the spatial evolution of a diffuse phenomenon
4. To determine the quality of coverage.
5. To achieve load balancing
6. To form clusters
7. To facilitate routing
8. To perform efficient spatial querying

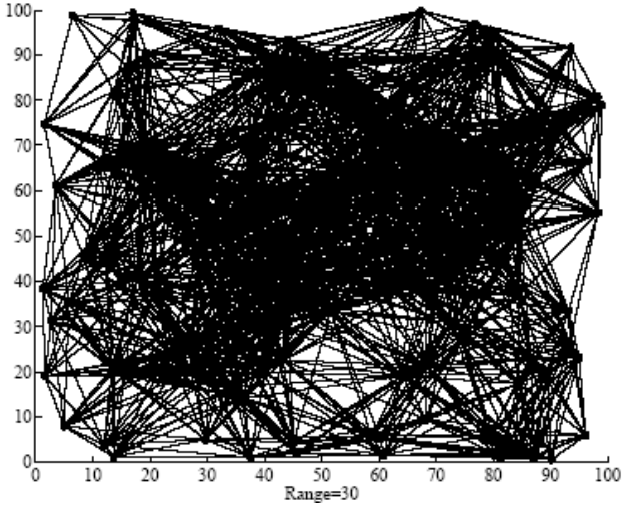
However, localization is only important in random deployment

What is a good topology?









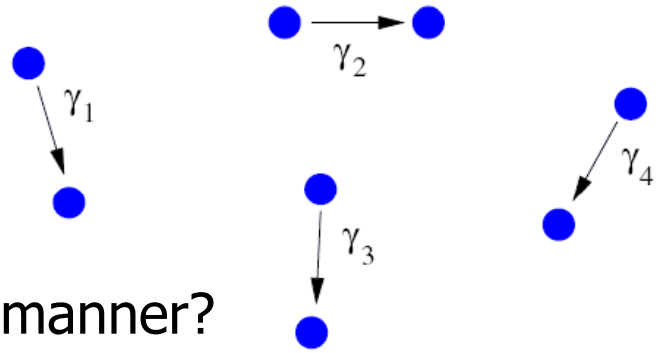
What is a good topology (Cont'd)

- Range must be large enough to ensure connectivity and connectivity must be robust with respect to node movements
- If range is too large some capacity is lost
- A common range for everyone is conceptually simple but not a good idea
- In real life nodes tend to cluster

Power Control

Once nodes decide who will transmit (with the MAC protocol), they need to decide with how much power they will transmit. This is the task of the power control protocol.

- Nodes interfere with each other.
- Each node has a target S/N γ_i
- Fundamental questions:
  - ➢ Is there a power P_i can achieve this γ_i ?
  - ➢ Can they be found in a distributed manner?
- All transmissions are with rate W.
  - $P_i(k)$ be the transmitter power of link i in slot k.
  - $R_i(k)$ be the measured SINR of link i in slot k.

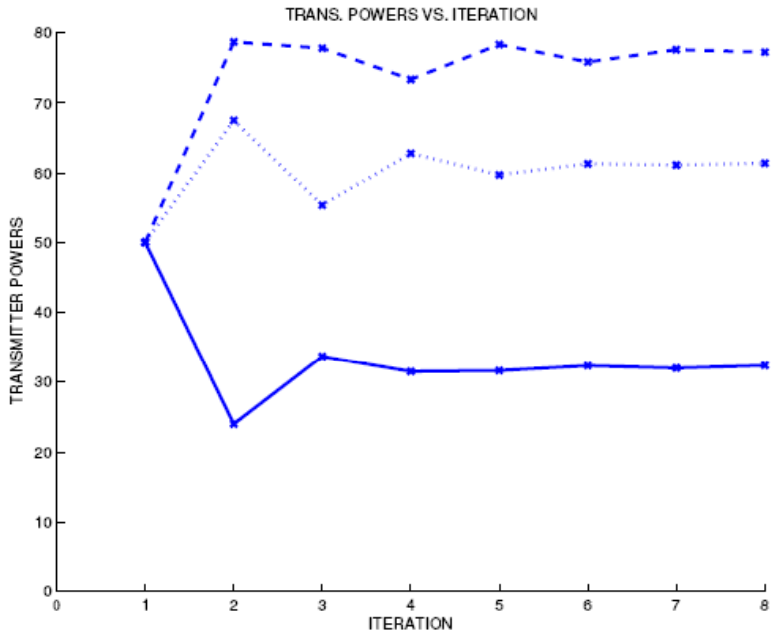


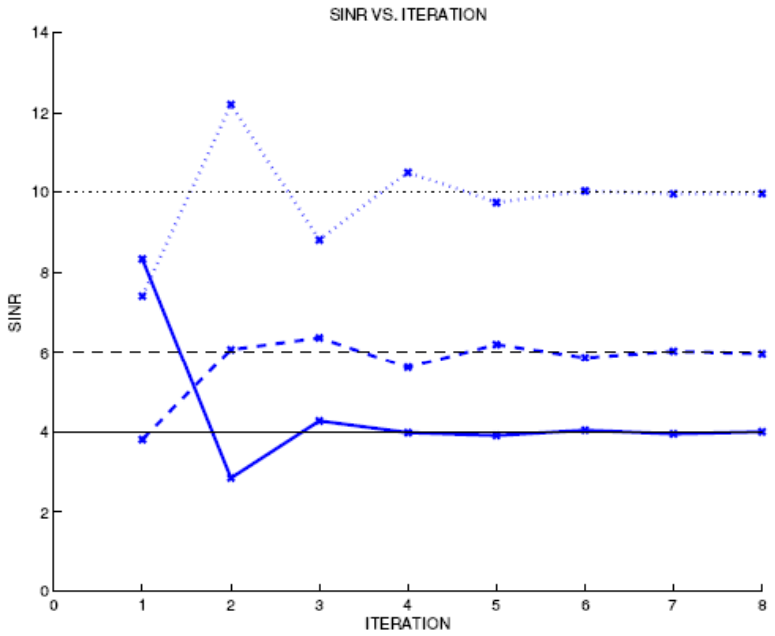
We set $P_i(k+1) = P_i(k)\frac{\gamma_i}{R_i(k)}$.

Distributed Power Control

If the problem is feasible, DPC will find the best solution:

1. The S/N will converge to the target values $\lim_{k\to\infty} R_i(k) = \gamma_i$.
2. The transmitter powers will be the minimum possible.

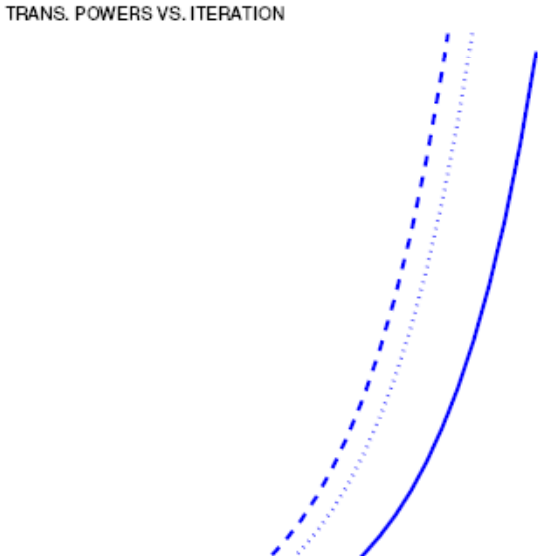


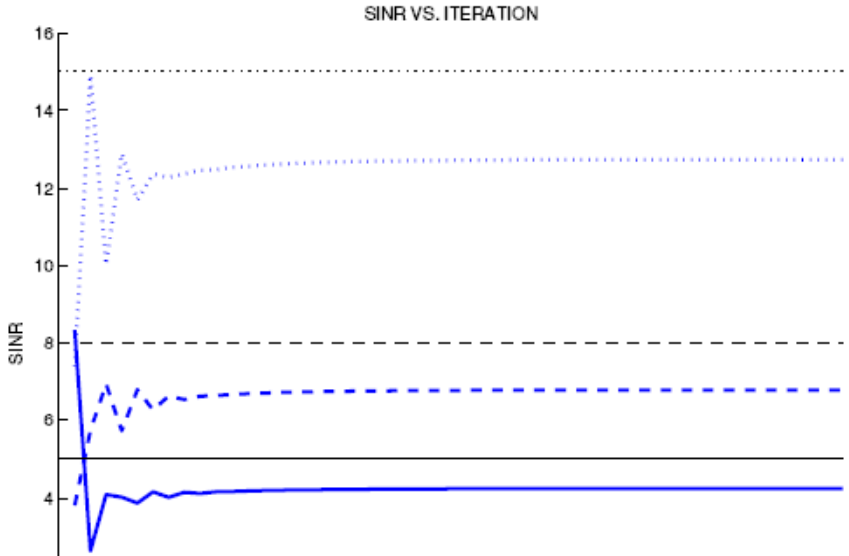


Distributed Power Control (Cont'd)

f the problem is not feasible:

1. The transmitters powers will go to infinity.
2. The S/N will converge to unacceptable values.





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