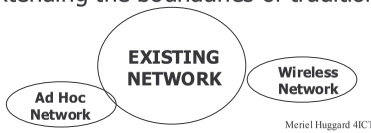
Ad Hoc Networks — What are they?

- An Ad-Hoc network is a collection of wireless mobile nodes that have the ability to dynamically form temporary networks without the use of any existing centralised network infrastructure
- Ad-Hoc networks employ routing management schemes that allow each network to **grow**, **reduce** in size or **fragment** in real-time without reference to any central authority

Ad Hoc Networks — Where would they be used?

- Civilian uses:
  - Impromptu business meetings, convention centres, construction sites
  - Emergency communications for disaster relief
- Military uses:
  - Sensor networks
  - Tactical communications between soldiers in the field
  - Provide robust communications in hostile environments
- Infrastructureless Environments:
  - Rapidly deployable in jungles, valleys, remote areas that do not have adequate communications infrastructure
- Extending the boundaries of traditional networks:



Ad Hoc Networks — Infrastructure-based networks

- Traditional networks with centralised intelligence include:
  - PSTN -Switches
  - GSM -Base Stations
  - IP, Mobile IP -Routers, Foreign/Home Agents
  - 3G -Packet Data Serving Nodes
- Fixed (slow moving) topologies:
  - Base-stations, routers and switches 'move' in a planned manner, otherwise they may be considered fixed
- Topologically significant addressing:
  - IP addresses -addresses topologically significant
  - Fixed-line telephones
  - GSM telephones } numbers are geographically/topologically significant

Ad Hoc Networks — Characterising an Ad Hoc Network

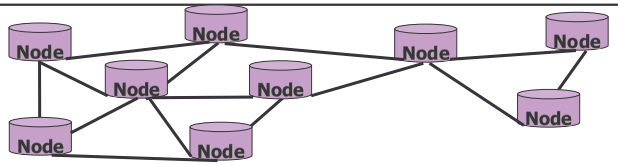
Traditional Networks

- **Power** – mains power consistent, full
- **Media** – Wire, Optic Fibre, Satellite generally symmetric links, high bandwidth, less error-pone
- **Processors** – Routers etc have large dedicated processors
- **Memory** – large memory for caching and processing routes, addresses

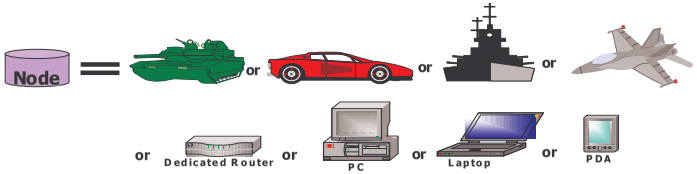
Ad Hoc Networks

- **Power** –batteries limited, inconsistent
- **Media** – Radio, IrDA (generally wireless media)
  - variable power will affect the signal strength of radios and leads to variable transmission abilities
  - limited bandwidth
  - symmetric/assymetric links
  - prone to errors
- **Processors**– Laptops and PDAs may be the target devices of ad hoc routing protocols – PDA ~ 266MHz, Laptops ~ 1GHz -not dedicated processors
- **Memory** – limited to 32/64 Mbytes RAM on a PDA

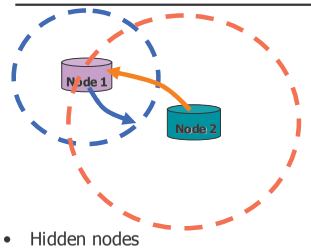
Ad Hoc Networks — What are the issues?



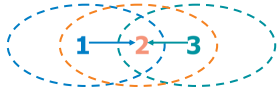
•The nodes of an ad hoc network may come in many forms, from dedicated routers and dedicated end-user terminals to machines that provide both types of functionality – routing and application level capabilities



Ad Hoc Networks — What are the issues?

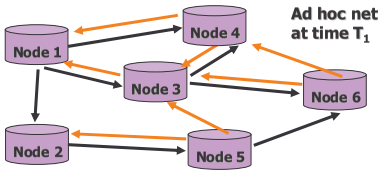


•A wireless ad hoc network may be more susceptible to asymmetric links than other networks
•The surrounding physical environment may significantly attenuate or distort the radio transmissions



- Hidden nodes
  - Node 1 can sense Node 2 but cannot sense Node 3, collisions, interference ensues – Node 3 is hidden from Node 1's perspective
- Exposed nodes
  - Node 3 senses Node 2 transmitting to Node 1 and unnecessarily delays its own transmission to Node 4

Ad Hoc Networks — What are the issues?

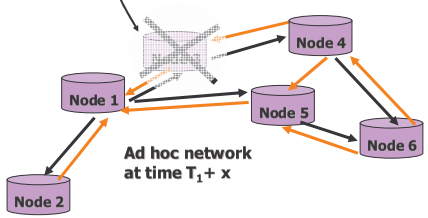


Ad hoc network at time T_1

•As the nodes of the network move the topology of the network will change

•The characteristics of the links may also change

•Nodes may also die or sleep, causing further changes



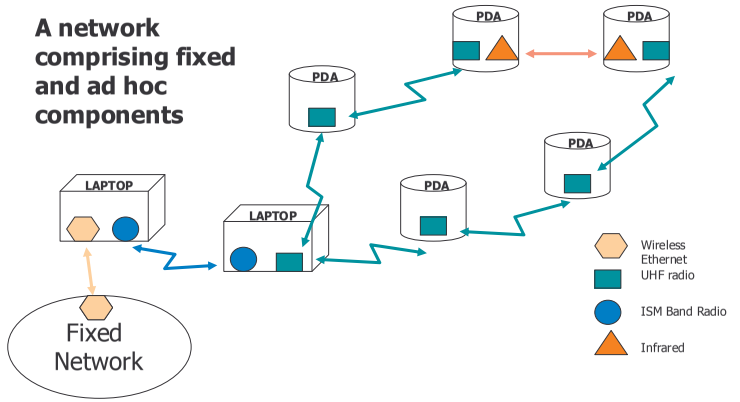
Ad hoc network at time T_1+ x

•Node velocities, densities and coverage areas may change from time to time

•An ad hoc network may be described as a distributed multi-hop network with a time-varying topology

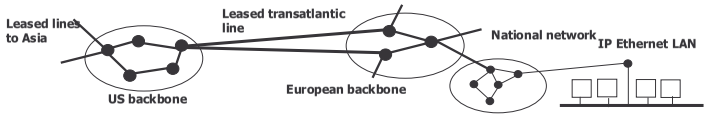
Ad Hoc Networks — Media and devices used

A network comprising fixed and ad hoc components



Ad Hoc Networks — Traditional Routing Approaches

- How is routing managed in the Internet?
  - Routers in the Internet are responsible for receiving and forwarding packets through an interconnected set of subnetworks.
  - Each subnetwork, any collection of routers controlled by a single entity, may be viewed as an **A**utonomous **S**ystem (**AS**) and routing within this system is done by an **interior routing protocol.** The protocol used in the various **AS**s may differ, as the protocol implemented inside one **AS** does not need to be implemented outside it.
  - Between these subnetworks (**AS**s), an **exterior gateway routing protocol** is used, normally **Border Gateway Protocol** (BGPv4).
  - An **AS** consists of a network connected by homogeneous routers and is a useful starting point for comparison with ad hoc networks



Ad Hoc Networks — Traditional Routing Approaches

- How does a router in an **AS** gain knowledge about the topology of the network?
  - While the Internet is not a very dynamic network, routers need to know about those parts of the network that are congested or that have failed.
  - In order to do this, routers need to exchange information about the status of different parts of the network:
    - Where can you get to from this router?
    - How much will it cost you (in hops, time etc) to get there?
  - Routing can be broken into two main concepts:
    - Routing Information - describes the topology and delays involved etc.
    - Routing Algorithm - making the routing decision for a datagram based on the known routing information
- **Remember: gathering routing information is not the function of IP, IP uses the routing information to forward packets**

Ad Hoc Networks — Traditional Routing Approaches - Distance-Vector

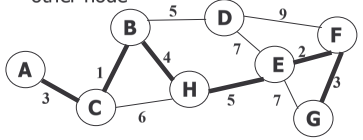
- There are two popular approaches to dynamic routing in networks of relatively stable topologies, such as an **AS**:
  - Distance-Vector routing
  - Link-State routing
- Distance-Vector (Bellman-Ford) routing:
  - It was the original ARPANET (U.S. Department of Defense Advanced Research Projects Agency Network) routing algorithm ~1960s
  - Used in initial interior routing protocol on the DARPA internet – released for IP under the name RIP (**R**outing **I**nformation **P**rotocol)
  - Each router maintains a routing table, indexed by, and containing one entry for, each router in the subnet
  - Each routing entry contains two parts:
    - The preferred outgoing path for that destination
    - The cost (time/distance) to get to that destination
  - It is assumed that a router **knows** the distance to its own neighbouring routers
  - Routers regularly inform their neighbours of their estimations of the metrics (delays/costs) involved to get to each destination

Ad Hoc Networks — Traditional Routing Approaches – Link-State

  - Consumes a lot of bandwidth as the network expands and the routing tables grow
  - For each path, the receiving routers pick the neighbour advertising the lowest cost, adding this entry to their own routing tables for re-advertisement
- In May 1979, distance-vector routing was replaced in the ARPANET by link-state routing. Why?
  - The delay metric for distance vector routing was queue length – it didn't take bandwidth into account since all lines were 56Kbps and when line bandwidth was upgraded to 230Kbps and 1.544Mbps this became a problem
  - The distance-vector approach took too long to converge
- How does link-state routing work?
  - Each router discovers its neighbours, their addresses and the cost of communicating with them
  - From time to time each router transmits updated state information to all the routers on its subnet, by flooding the subnet
  - Updates are minimal because the link-state descriptions are small and rarely need to be sent – network topology changes are relatively infrequent

Ad Hoc Networks — Traditional Routing Approaches – Link-State

- As routers build up link-state information they individually compute the shortest path to every other router based on the link-state information received
- The complete topology and all delays (metrics) are experimentally measured and distributed to every router
  - How would you learn about your neighbours when booted up for the first time?
    - HELLO packets
  - How is the link cost measured?
    - ECHO packets
- Uses less bandwidth than the distance-vector approach
- Uses Djikstra's algorithm to compute shortest path from each node to every other node



It is common to represent routing topologies as graphs, the vertices being the routers and the edges weighted in proportion to the costs

Shortest path not necessarily fewest edges

Least cost Route from **A** to **G**

Ad Hoc Networks — Traditional Routing Approaches

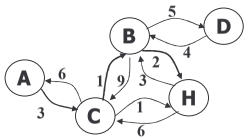
- More complex to implement
- Routers perform their own independent computations
- Intermediate System-Intermediate System (**IS-IS**) is a link-state protocol which was initially adopted by ISO for use with **C**onnectionless **N**etwork **L**ayer **P**rotocol (**CNLP**) and has since been adapted for use with **IP**
- In 1990 the current popular interior Internet protocol, the link-state **O**pen **S**hortest **P**ath **F**irst routing protocol (**OSPF** RFC 1247), which was designed years after IS-IS and adopted many of its innovations, was stanardised by the **IETF**

- Why did they choose **OSPF**?
  - It was OPEN, a non-proprietary solution that anyone could implement
  - It supports a variety of metrics – physical distance, delay, dollar cost
  - Adapts to changes in network topology dynamically and quickly

Ad Hoc Networks — Traditional Routing Approaches

- Supports routing based on Type of Service (TOS), one of the IP fields, meaning that it could establish routes of varying quality and speed – a form of load balancing

- How does it work?
  - **OSPF** abstracts the collection of networks, routers and connections into a directed graph
  - It computes the shortest path based on the weights of the edges
  - A connection between two routers may be represented by a directed pair of edges, each of different weighting since links may be asymmetric
  - Since OSPF allows for the computation of routes based on differing metrics – delay, throughput, reliability – a router may have several graphs for a single network as the optimal routes are not necessarily the same for each metric



Ad Hoc Networks — Ad Hoc Routing Protocols

- Are these protocols suitable for Ad Hoc networks? **NO**
- Why?
  - Remember the limitations:
    - Low variable power
    - Low variable transmission bandwidth
    - Error-prone transmission
    - MAC problems
    - Nodes in an ad hoc network serve as routers and end-user terminals, so their hardware is not dedicated solely to routing issues
  - The protocols we've looked at have dedicated, immobile, powerful routers with high bandwidth transmission capabilities at their core – almost diametrically opposite to the characteristics of an ad hoc network

Ad Hoc Networks — Ad Hoc Routing Protocols

- **What qualities should an ad hoc routing protocol possess?**
  - It should be flexible and dynamic, adapting to the characteristics of the underlying network, those characteristics ranging from node velocity, node battery power and node transmission ability to node CPU power
  - Nodes **must** consume bandwidth judiciously, due to power and transmission limitations
  - Distance-Vector protocols can take a long time to converge, i.e. the toplogy information spreads slowly throughout the network, they also use large update messages – not ideal candidates
  - While link-state protocols have come to solve a lot of these problems for wired networks, converging more quickly, they still utilise a lot of control traffic and aim to have a view of the whole network – not very pragmatic when dealing with a mobile ad hoc network
  - The motivation should be to improve the protocol's convergence abilities and reduce traffic, bearing all the criteria mentioned in mind

Ad Hoc Networks — Ad Hoc Routing Protocols

- Current ad hoc routing protocol proposals fall in to one of three categories:
  - On-Demand protocols
    - Temporally Ordered Routing Algorithm (TORA)
    - Dynamic Source Routing (DSR)
    - Ad-Hoc On Demand Distance Vector (AODV)
  - Table-Driven protocols
    - Optimised Link State Routing (OLSR)
    - Destination Sequenced Distance Vector (DSDV)
    - Fisheye State Routing Protocol (FSR)
  - Hybrid protocols
    - Zone Routing Protocol (ZRP)
- These protocols are actively investigated under the guidance of the IETF working group on **M**obile **A**d Hoc **Net**works, **MANET** **(www.ietf.org/html.charters/manet-charter.html)**