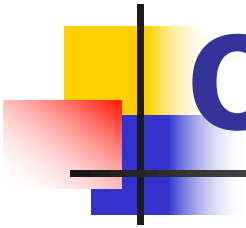
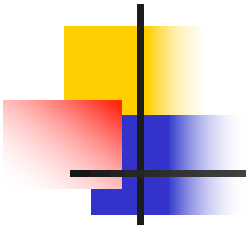
Ad-hoc Networking &WPAN



Outline

- Ad-Hoc Networking?
  - Why?
  - What?
  - How?
  - When? : Past, Present, Future

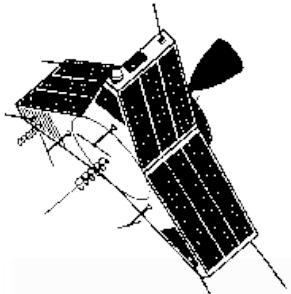


Scenario

- **The advent of cheap microprocessors and wireless technologies**

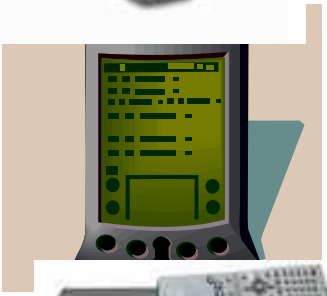
- **Trend: ~1000 computer devices/person by 2010**

Use Cases





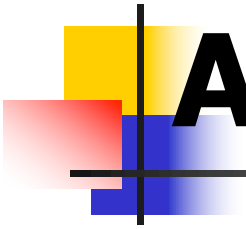




Possibilities

- Telephones (cellular, cordless, other)
- Cordless multimedia (headsets, speakers, mic.)
- Portable computers (Laptops, desktop, other)
- Cordless computer peripherals (keyboard, mouse)
- LAN – Local Area Network peripherals (printer, fax)
- PDAs - Personal Digital Assistants (palm top/pilot)
- Digital cameras



Ad-…what?

Ad-hoc network…

…a LAN or other small network,

…with wireless connections

…devices are part of the network only for the duration of a communications session

Or …while in close proximity to the network

Ad-hoc Networking

Collection of wireless mobile nodes (devices)

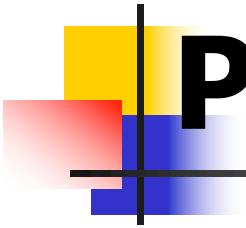
dynamically forming a temporary network

without the use of any existing network infrastructure or centralized administration

An ubiquitous type of computing often referred to as pervasive/invisible computing

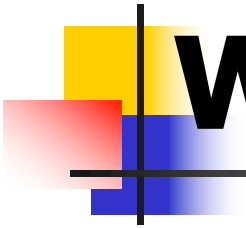
•Ubiquitous: Present, appearing, or found everywhere…

•Pervasive: Spread through or into every part of…



Properties

- Requires devices to cooperate autonomously
- Without user intervention
- Rapid self-organizing wireless network
- Independent of infrastructure
- Heterogeneous & adaptive



Why?

Microprocessor embedding trend in:

- **cellular phones, car stereos, televisions, VCRs, watches, GPS (Global Positioning System) receivers, digital camera.**

- **Ensembles of computational devices for:**
  - **environmental monitoring**
  - **personal area networks**
  - **geophysical measurement**

How?

Transmission Standards:

1. **Piconet**

2. **HomeRF (Radio Frequency)**

3. **IEEE 802.11 Wireless LAN WG (Working Group)**

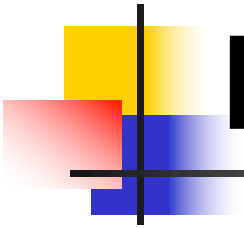
4. **Bluetooth SIG (Special Interest Group)**

   - **These above use radio waves from licence-exempt ISM (Industrial, Scientific and Medical) frequency band - around 2.4 GHz**

5. **IrDA (InfraRed Data Association)**
   - **which uses infrared instead of radio waves**

Piconet

- A general purpose, low-powered, ad-hoc network
- It allows two devices near each other to inter-operate
- These devices can be either mobile or fixed
- The range is said to be reasonably short



HomeRF

Uses Shared Wireless Access Protocol (SWAP) system

- **carries both voice and data traffic**
- **inter-operate with the PSTN (Public Switched Telephone Network) and the Internet**
- **the range covers typical home and yard**

IEEE 802.11 Wireless LAN

The principles of Wireless Local Area Network (WLAN) are defined in IEEE 802.11 standard

- **It defines two different topologies: ad-hoc network and infrastructure network**
- **This ad-hoc network is able to use only created wireless connection instead of fixed infrastructure**

Bluetooth

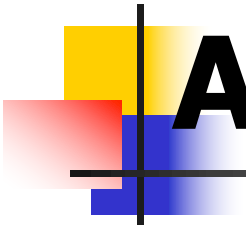
- The code name for an open specification for short-range wireless connectivity
- Effortless, instant wireless connections between a wide range of communication devices in a small environment
- The BT range restricts the environment to about 10 meters
- Used in virtually any mobile device like that can have Bluetooth radios integrated into them

IrDA

- based on technology similar to the remote control devices
- high-speed short range, point-to-point cordless data transfer
- in-room cordless peripherals to host-PC
- maturity and standardization activities advantage over radio
- line-of-sight requirement disadvantage

Wireless comparison

	Bluetooth	HomeRF	EEE802.11	IrDA	Piconet
Unit Cost	$ 20 > $ 5	TBD	$ 300	< $ 5	N/A
Throughput	1+ Mbps	1+ Mbps	1 - 11 Mbps	9.6 kbps - 4 Mbps	40 kbps
Security	Key exchange	Blowfish encryption	Key exchange	??	-
RF power	1 mwatt+	100 mwatts	100 mwatts	N/A	250 mwatts
Range	40 feet	100 feet	100+ feet	Line of sight	low-range ?



Applications

Some current deployments, research and prospects

- **Cybiko**
- **Sensor Networks e.g. *"Smart Dust"***
- **Mobile Commerce (M-Commerce) - proposed**

ko

•like a Palm Pilot, except with free games and and is designed for entertainment unlike palms which are really meant as organisers

•wireless connectivity RF transmitter for text chat

- when cybikos network together, they relay messages to other cybikos, which allows the range to be increased
- up to 100 cybikos can be networked in this way, and 3000 cybikos can be online in one area at once before the ISM RF band gets full
- it will have a range of approx. 1km outside, 500m inside

Sensor Nets – "*Smart Dust*" I

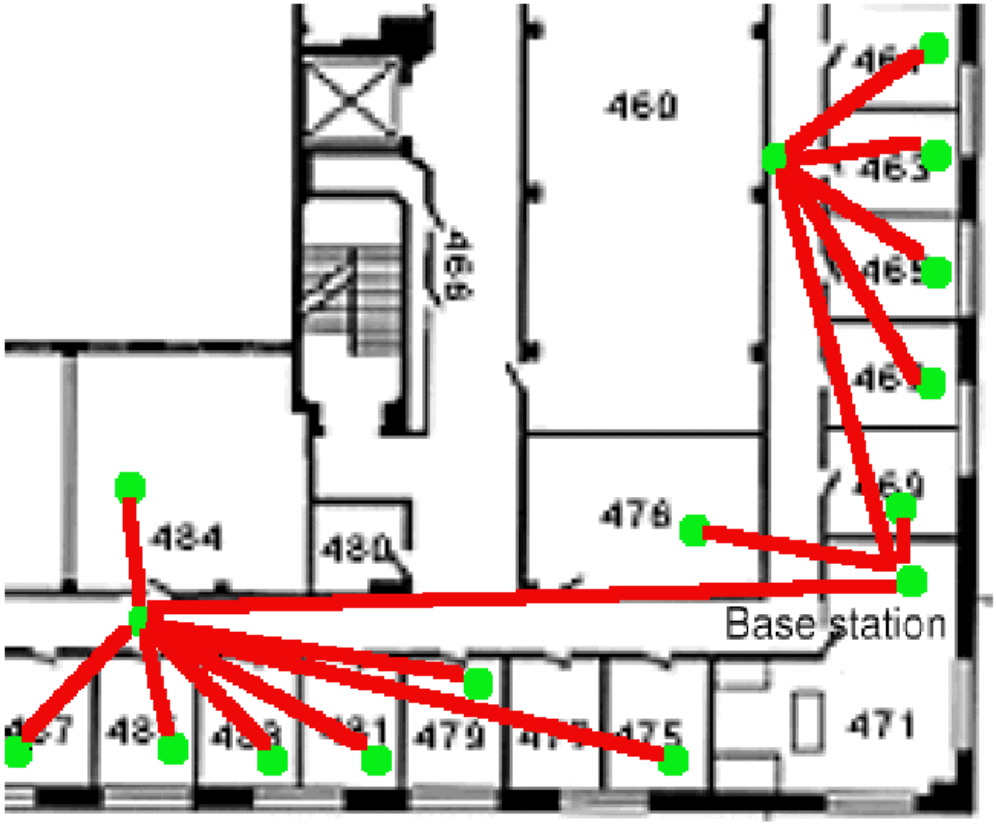
- **thousands to millions of small sensors form self-organizing wireless networks**

- **consists of *node*s, small battery powered devices, that communicate with a more powerful *base station*, which in turn is connected to an outside network.**

Sensor Nets – "*Smart Dust*" II

Metrics:

CPU	8-bit, 4MHz
Storage	8KB instruction flash 512 bytes RAM 512 bytes EEPROM
Communication	916 MHz radio
Bandwidth	10 kbps
Operating System	TinyOS
OS code space	3500 bytes
Available code space	4500 bytes



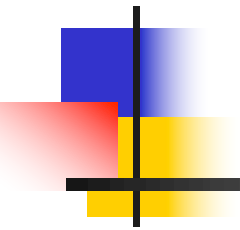
- Node to base station communication, e.g. sensor readings
- Base station to node communication, e.g. specific requests
- Base station to all nodes, e.g. routing beacons, queries or reprogramming of the entire network

M-Commerce

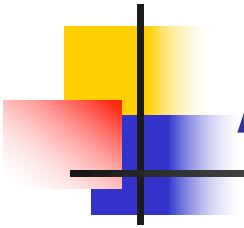
- Mobile phones to extend the possibilities of commerce
- make commerce platforms more important
- electronic and mobile commerce transactions will be open for wide markets

Issues & Interests

- What do you see as the next interesting things in mobile computing?
- What potential do you see for wireless networks?
- What do you see as the hardest things for us to address? Security for one!
- If you could wish for one key piece of technology to come true (for mobility), what would it be?



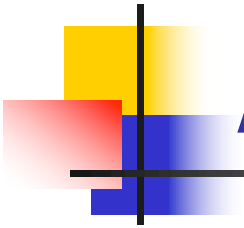
Ad Hoc Networks and Their Protocols:



Ad Hoc Networking

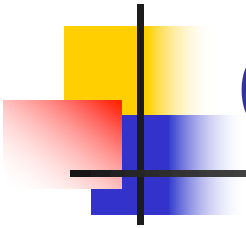
A mode of loosely connected networking characterized by the following qualities:

- lack of fixed infrastructure
- peer-to-peer (all nodes act as routers)
- multi-hop routing
- frequent connection / topology changes



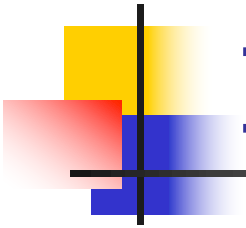
Applications of Ad Hoc

- Earliest uses: military
- law enforcement
- emergency search-and-rescue teams
- business / commercial
- conventions / expos
- data acquisition



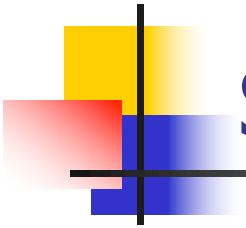
Challenges Facing Ad Hoc

- Security
- scalability
- load balancing / etiquette between hosts
- QoS
- CPU/memory overhead
- effect on devices' battery life



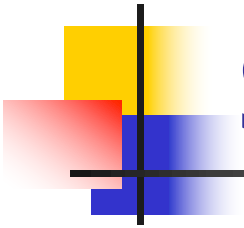
Issues in Protocol Design

- Must run in distributed environment
- must provide loop-free routes
- must be able to find multiple routes
- must establish routes quickly
- must minimize overhead in its communication / reaction to topology change



Some Implementation Choices

- Flat vs. hierarchical architecture
- proactive vs. reactive to topology changes
- table-based, demand-driven, associativity-driven
- topology change dissemination methods
- when/how often to exchange topology info
- assumptions about rate of change of topology and/or quality of connections



Some Ad Hoc Protocols

- DARPA (1970s military packet radio)
  used with SURAN (SURvivable Adaptive Network; an early ad hoc networking testbed)
- CGSR (hierarchical)
- TORA (time-based; uses link reversal)
- DSR
- AODV

CGSR: Hierarchical Routing

- All nodes send their data to cluster head nodes
- heads act as second tier, high-power network
- +: simpler routing
  -: poor load balancing,
  not secure

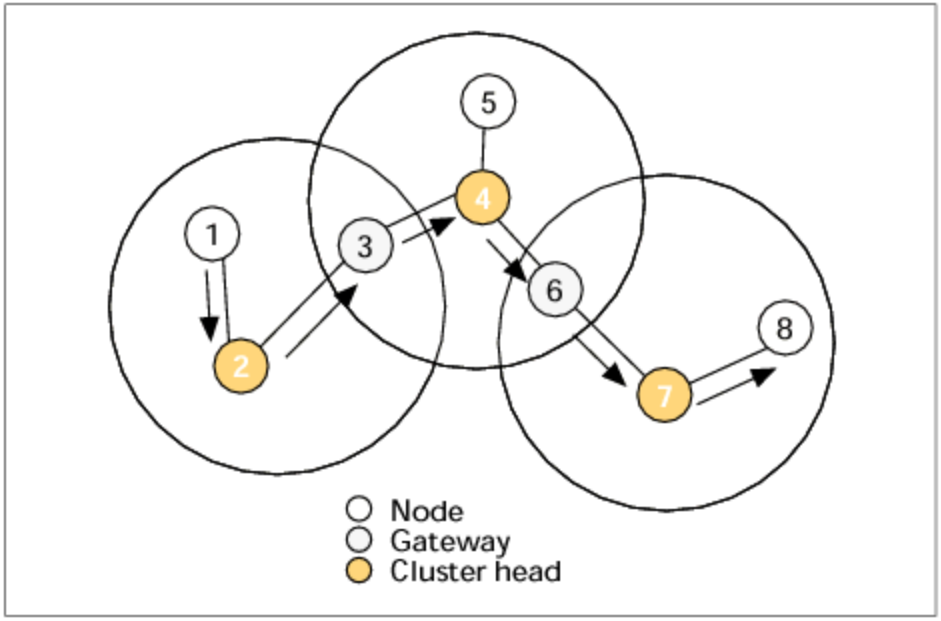
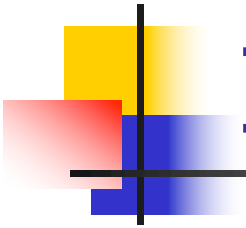


Figure 2. *CGSR: routing from node 1 to node 8.*



In-Depth: AODV

(Ad-hoc On-demand Distance Vector routing)

- purely on-demand (no routes determined until needed)
- each node contains routing table of next-hop information for how to get to every other node

AODV Path Discovery

- Source node broadcasts a path discovery
- message continues until it reaches destination, or node with path in table
- sequence nums
- discovery response sent back along reverse path

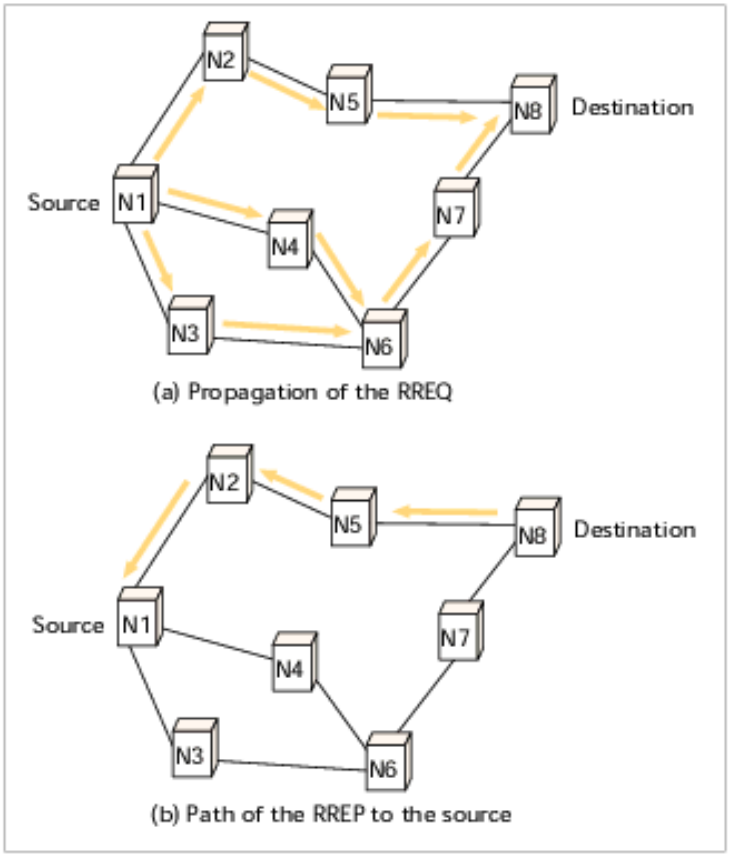
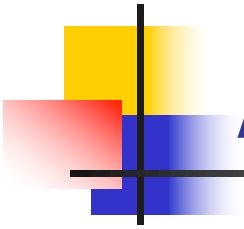
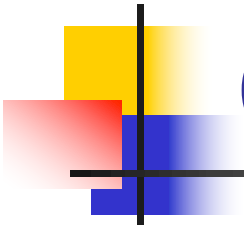


Figure 3. *AODV route discovery.*



AODV Path/Connection Maintenance

- Nodes 'ping' with *hello* messages to test links
- timeouts assumed to be broken links
- (only) recent active nodes notified of topology changes--propogated to neighbors



Contrast: DSR

(Dynamic Source Routing)

- resides in kernel IP layer (based on IPv6 format)
- nodes contain tables of *full paths* to other nodes
- messages: Route Request, Route Reply, Route Error, ACK
- Send, Retransmit buffers
- passive ACK

DSR Route Discovery

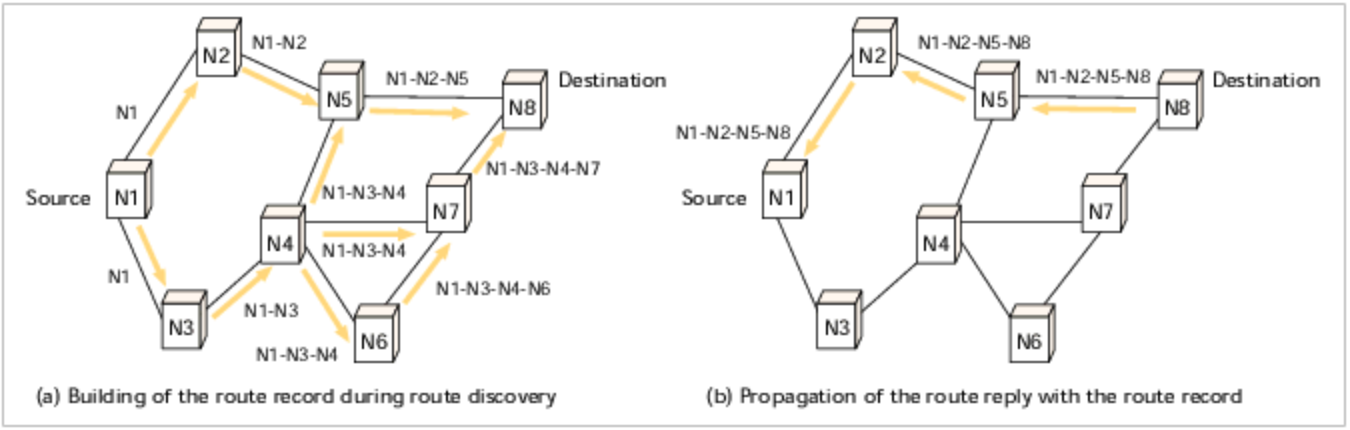
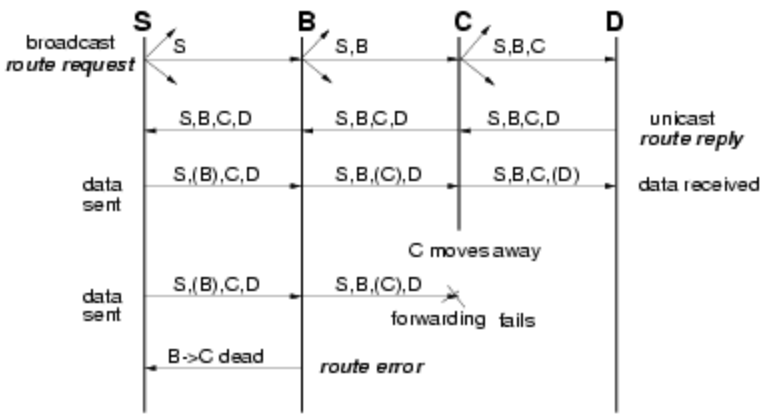


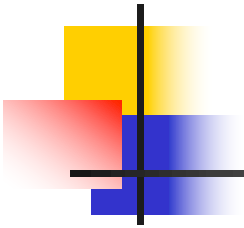
Figure 4. *Creation of the route record in DSR.*

- **One-hop** Route Request (ask immediate neighbors)
- if that fails, **broadcast** request to whole network
- Route Reply is sent by destination or node with path in **cache**

DSR Route/Connection Maintenance

- Repeated failed requests to retransmit packets cause a Route Error message
- on-demand; no pinging
- all nodes in Route Error chain update their caches
- source can again do Route Discovery

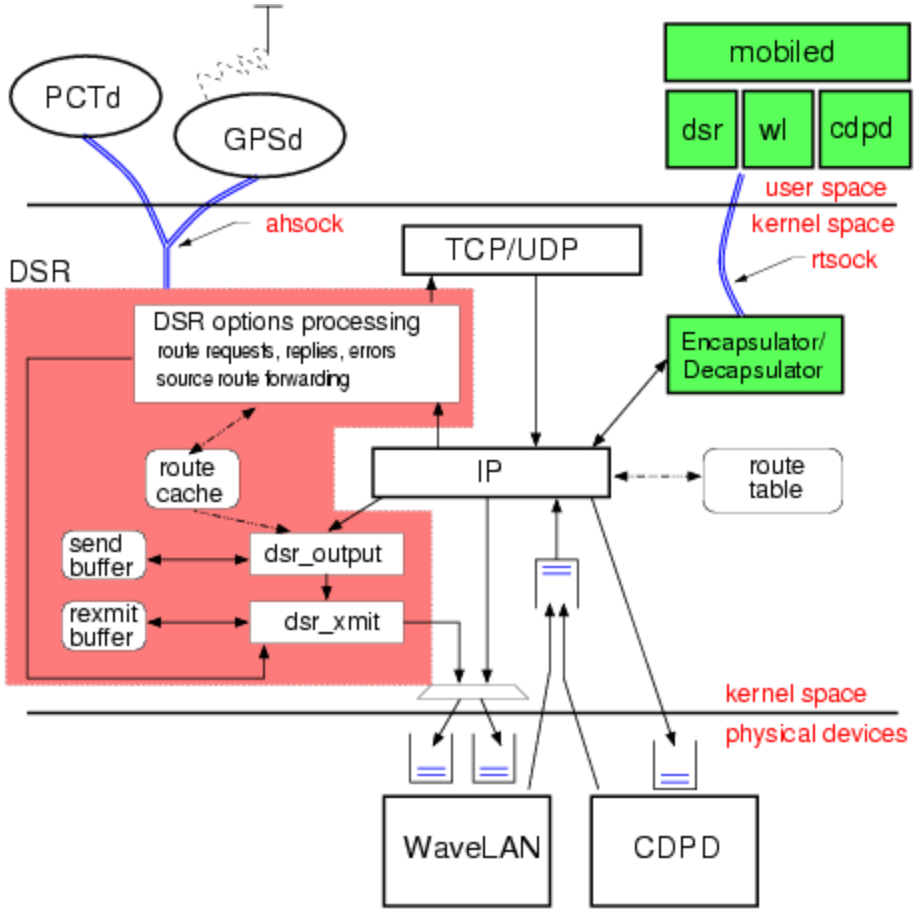




DSR Ack and Retransmit

- Passive ACK - listen in promiscuous mode to see if neighboring nodes are forwarding
- duplicate detection
- adaptive retransmit - uses length of transmit queue to bump up retrans time during periods of network congestion
- multi-level packet priority queue (IP TOS field)

How DSR Fits into Testbed



DSR vs. AODV

	DSR	AODV
routing table format	full path	next hop
route checking	passive acks	'hello' pings
rate of propogation of topology changes	fast	slower
ability to handle frequent topology change	good	fair
CPU / memory usage	high	low
scalability	poor	excellent

More Protocol Comparisons

Performance parameters	AODV	DSR	TORA	ASR	SSR
Time complexity (initialization)	$O(2d)$	$O(2d)$	$O(2d)$	$O(d + z)$	$O(d + z)$
Time complexity (postfailure)	$O(2d)$	$O(2d)$ or 0*	$O(2d)$	$O(l + z)$	$O(l + z)$
Communication complexity (initialization)	$O(2N)$	$O(2N)$	$O(2N)$	$O(N + y)$	$O(N + y)$
Communication complexity (postfailure)	$O(2N)$	$O(2N)$	$O(2x)$	$O(x + y)$	$O(x + y)$
Routing philosophy	Flat	Flat	Flat	Flat	Flat
Loop-free	Yes	Yes	Yes	Yes	Yes
Multicast capability	Yes	No	No**	No	No
Beaconing requirements	No	No	No	Yes	Yes
Multiple route possibilities	No	Yes	Yes	No	No
Routes maintained in	Route table	Route cache	Route table	Route table	Route table
Utilizes route cache/table expiration timers	Yes	No	No	No	No
Route reconfiguration methodology	Erase route; notify source	Erase route; notify source	Link reversal; route repair	Localized broadcast query	Erase route; notify source
Routing metric	Freshest and shortest path	Shortest path	Shortest path	Associativity and shortest path and others***	Associativity and stability

Abbreviations:
l = Diameter of the affected network segment
y = Total number of nodes forming the directed path where the REPLY packet transits
z = Diameter of the directed path where the REPLY packet transits
* Cache hit.
** Like CGSR, TORA also does not support multicast; however, there is a separate protocol, LAM [18], which runs on top of ORA and provides multicast capability.
*** ABR also uses the route relaying load and cumulative forwarding delay as routing metrics.