Chapter 16

Wireless LAN, Mobile Ad Hoc Networks, and MANET Routing Protocols

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Wireless Network Models

- With Infrastructure:
- Without Infrastructure (ad hoc networks):

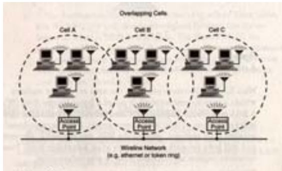


Figure 2.9
A multiple-cell wireless LAN.

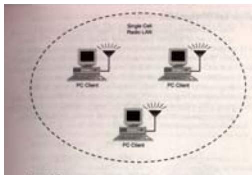
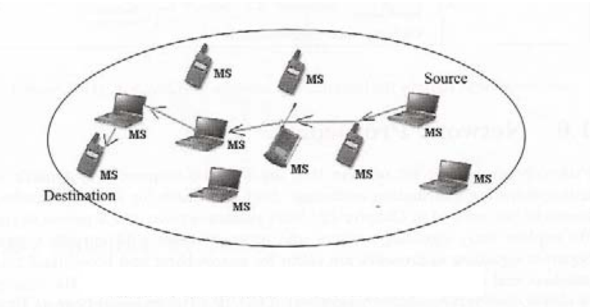


Figure 2.8
A single-cell wireless LAN.

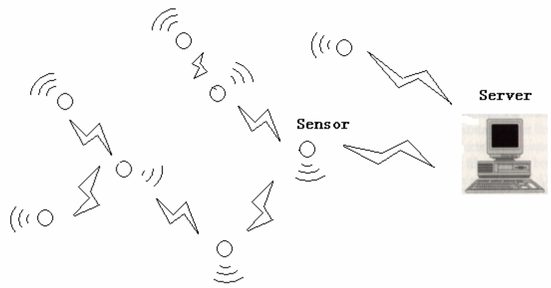
Various Wireless Network Models

	outside the office		quality of service	
Home networking	To connect different PCs in the house to share files and devices such as printers	Anywhere in the house	Limited to a home	Netgear Phoneline 10X, Intel AnyPoint Phoneline Home Network, 3Com Home Connect Home Network Phoneline
Ad hoc networks	Group of people come together for a short time to share data	Equal to that of local area network, but without fixed infrastructure	Limited range	Defense applications
Sensor networks	A large number of tiny sensors with wireless capabilities	Relatively small terrain	Very limited range	Defense and civilian applications
Bluetooth	All digital devices can be connected without any cable	Private ad-hoc groupings away from fixed network infrastructures	Range is limited due to the short-range radio link used	Home devices

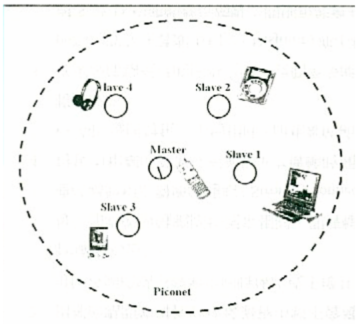
Illustration of an ad hoc network



Wireless Sensor Networks (WSNET)



Bluetooth Scatternet



圖四：所有Bluetooth設備都有一個內部系統時序CLKN

Wireless LAN and PAN Techniques

Table 1.12 Noteworthy Wireless LAN and PAN Techniques

Type of Network	Range of Node	Primary Function	Deployed Locations
IEEE 802.11	30 meters	A standard for wireless nodes	Any peer-to-peer connection
HiperLAN	30 meters	High-speed indoor connectivity	Airports, warehouses
Ad Hoc Networks	≥500 meters	Mobile, Wireless, similar to wired Connectivity	Battlefields, disaster locations
Sensor Networks	2 meters	Monitor inhospitable or inaccessible terrain cheaply	Nuclear & chemical plants, ocean, etc.
HomeRF	30 meters	Share resources, connect devices	Homes
Ricochet	30 meters	High-speed wireless Internet access (128 Kbps)	Airports, offices
Bluetooth Networks	10 meters	Avoid wire clutter, provide low mobility	Offices

Comparison between 802.11 Protocols and Bluetooth

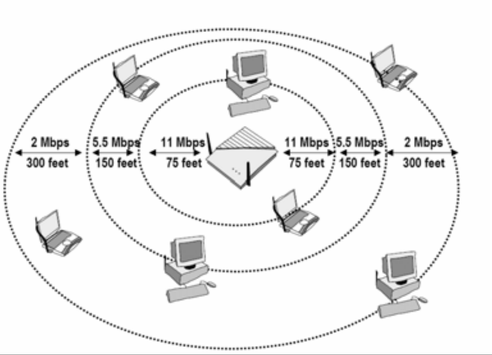
TABLE 1.2 Comparison between Key 802.11 Protocols and Bluetooth

WLAN	802.11a	802.11b	Bluetooth
Transport	5-GHz UNII DSS	2.4-GHz ISM FHSS/DSS	2.4 GHz ISM FHSS
Data rate	6–54 Mbit/s	1–11 Mbit/s	1 Mbit/s
Range	*	50 m	1–10 m
Power	0.05/0.25/1 W	+20 dBm	0 dBm

*If used with an external antenna, the WLAN can be extended beyond the immediate office environment.

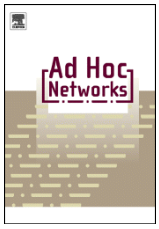
Note: DSS = direct sequence spread spectrum, FHSS = frequency-hopping spread spectrum, W = watts, dBm = decibels referenced to 1 milliwatt.

The Data Rate vs. Distance



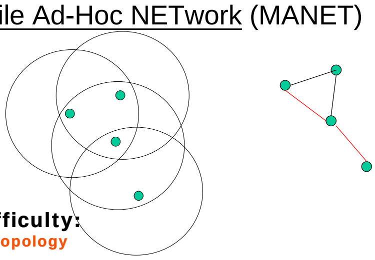
Outline of Mobile Ad Hoc Networks

- Routing = Ants Searching for Food
- Introduction to Ad Hoc Wireless Networks
- Ad-Hoc Routing Protocols (Proactive vs. Reactive)
- **Ad Hoc Networks**



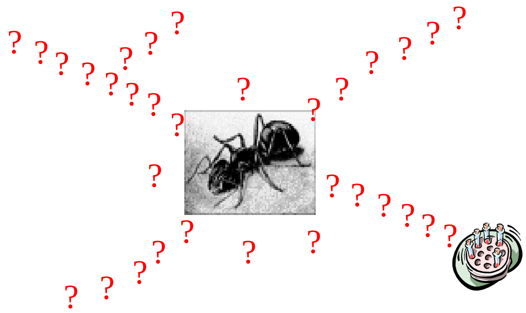
Problem Definition

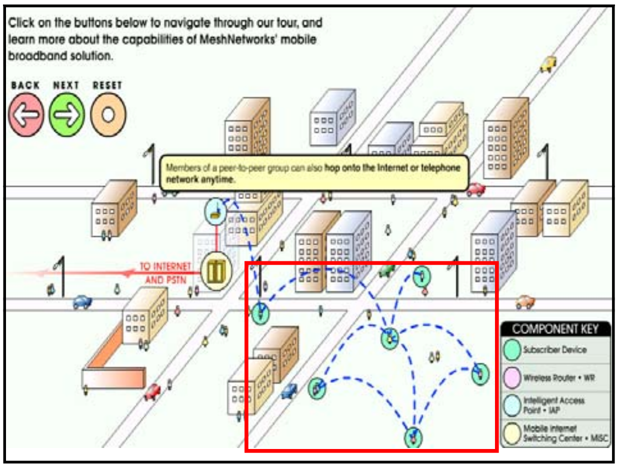
- Design efficient routing protocols in Mobile Ad-Hoc NETwork (MANET)



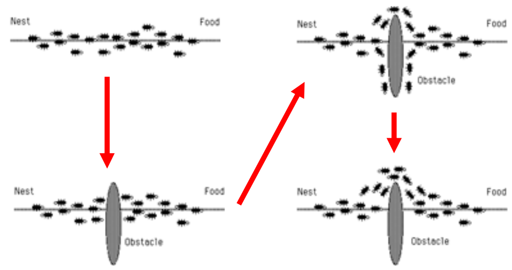
Design Difficulty:
Changeable Topology

Routing = Ants Searching for Food





Example:



Three Main Issues in Ants' Life

- Route Discovery:
  - Searching for the places with food
- Packet Forwarding:
  - Delivering foods back home
- Route Maintenance:
  - When foods move to new place

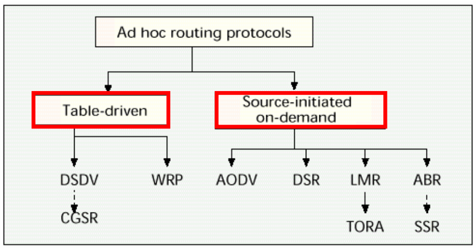
Mobile Ad Hoc Networks

- Infrastructureless mobile network
- No fixed routers, no base stations
- All nodes can move and be connected dynamically
- All nodes is treated as routers
- Application
  - battlefield, disaster areas

Challenge of Ad Hoc NETs

- No centralized entity
- Host is no longer just an end system
- Acting as an intermediate system
- Changing network topology over time
- Every node can be mobile

Overview of current approaches



Proactive vs. Reactive Routing

- Proactive Routing Protocol (Table-Driven)
  - Continuously evaluate the routes
  - Attempt to maintain consistent, up-to-date routing information
    - When a route is needed, one may be ready immediately
  - When the network topology changes
    - The protocol responds by propagating updates throughout the network to maintain a consistent view
- Reactive Routing Protocol (On-Demand-Drien)
  - Ex: DSR, AODV

On-demand vs Table-driven

Parameters	*On-demand*	*Table-driven*
Availability of routing information	Available when needed	Always available regardless of need
Routing philosophy	Flat	Mostly flat, except for CGSR
Periodic route updates	Not required	Required
Coping with mobility	Use localized route discovery as in ABR and SSR	Inform other nodes to achieve a consistent routing table
Signaling traffic generated	Grows with increasing mobility of active routes (as in ABR)	Greater than that of on-demand routing
Quality of service support	Few can support QoS, although most support shortest path	Mainly shortest path as the QoS metric

Table-Driven Routing

- DSDV: Destination Sequence Distance Vector
- CGSR: Clustered Gateway Switch Routing

DSDV

- Destination Sequenced Distance Vector
  - Table-driven
  - Based on the distributed Bellman-Ford routing algorithm
  - Each node maintains a routing table
    - Routing hops to each destination
    - Sequence number

DSDV

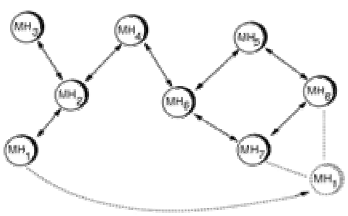


Figure 1: Movement in an ad-hoc network

DSDV(cont.)

Destination	NextHop	Metric	Sequence number	Install	Stable_data
MH_1	MH_2	2	S406_MH_1	T001_MH_4	Ptr1_MH_1
MH_2	MH_2	1	S128_MH_2	T001_MH_4	Ptr1_MH_2
MH_3	MH_2	2	S564_MH_3	T001_MH_4	Ptr1_MH_3
MH_4	MH_4	0	S710_MH_4	T001_MH_4	Ptr1_MH_4
MH_5	MH_6	2	S392_MH_5	T002_MH_4	Ptr1_MH_5
MH_6	MH_6	1	S076_MH_6	T001_MH_4	Ptr1_MH_6
MH_7	MH_6	2	S128_MH_7	T002_MH_4	Ptr1_MH_7
MH_8	MH_6	3	S050_MH_8	T002_MH_4	Ptr1_MH_8

Table 1: Structure of the MH_4 forwarding table

Destination	Metric	Sequence number
MH_1	2	S406_MH_1
MH_2	1	S128_MH_2
MH_3	2	S564_MH_3
MH_4	0	S710_MH_4
MH_5	2	S392_MH_5
MH_6	1	S076_MH_6
MH_7	2	S128_MH_7
MH_8	3	S050_MH_8

Table 2: Advertised route table by MH_4

DSDV(cont.)

Destination	NextHop	Metric	Sequence number	Install	Stable_data
$\mathbf{MH_1}$	$\mathbf{MH_6}$	3	$S516\_MH_1$	$T810\_MH_4$	$Ptrl\_MH_1$
MH_2	MH_2	1	$S238\_MH_2$	$T001\_MH_4$	$Ptrl\_MH_2$
MH_3	MH_2	2	$S674\_MH_3$	$T001\_MH_4$	$Ptrl\_MH_3$
MH_4	MH_4	0	$S820\_MH_4$	$T001\_MH_4$	$Ptrl\_MH_4$
MH_5	MH_6	2	$S502\_MH_5$	$T002\_MH_4$	$Ptrl\_MH_5$
MH_6	MH_6	1	$S186\_MH_6$	$T001\_MH_4$	$Ptrl\_MH_6$
MH_7	MH_6	2	$S238\_MH_7$	$T002\_MH_4$	$Ptrl\_MH_7$
MH_8	MH_6	3	$S160\_MH_8$	$T002\_MH_4$	$Ptrl\_MH_8$

Table 3: MH_4 forwarding table (updated)

Destination	Metric	Sequence number
MH_4	0	$S820\_MH_4$
MH_1	3	$S516\_MH_1$
MH_2	1	$S238\_MH_2$
MH_3	2	$S674\_MH_3$
MH_5	2	$S502\_MH_5$
MH_6	1	$S186\_MH_6$
MH_7	2	$S238\_MH_7$
MH_8	3	$S160\_MH_8$

Table 4: MH_4 advertised table (updated)

DSDV

- Problem
  - A lot of control traffic in the network
- Solution
  - two types of route update packets
    - Full dump
      - All available routing information
    - Incremental
      - Only information changed since the last full dump

On-Demand Routing

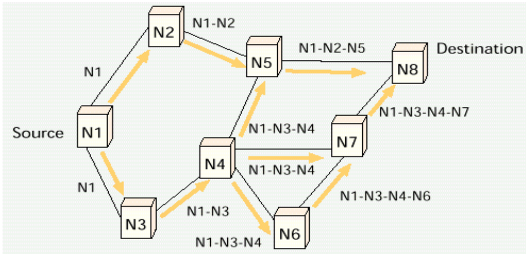
- DSR(Dynamic Source Routing)
- AODV(Ad Hoc On-Demand Distance Vector)
- TORA(Temporally Ordered Routing Algorithm)
  - MER-TORA (micromobility protocol)
    - IP Mobility
    - Support handover solutions
- LAR(Location-Aware Routing)
- ZRP(Zone Routing Protocol)
- SSA(Signal Stability-Based Adaptive Routing)
- …

DSR(Dynamic Source Routing)

DSR

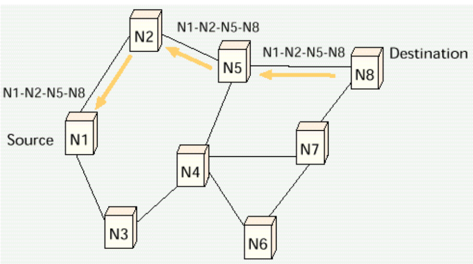
- Dynamic Source Routing [1996]
  - On-demand driven
  - Based on the concept of source routing
  - Required to maintain route caches
  - Two major phases
    - Route discovery
    - Route maintenance
      - A route error packet

DSR



(a) Building of the route record during route discovery

DSR(cont.)



(b) Propagation of the route reply with the route record

DSR: Route Request(RREQ)

Type=REQ	Option Length	Idetification	
Target Address			
index1	index2	index3	index4
Address1			
Address2			
Address3			
Address4			

Figure 1: The ROUTE_REQ packet used in DSR. The *option length* field can be used to calculate the number of addresses appended.

DSR: Route Reply(RREP)

Type=REPLY	Option Length	R	F	Reserved
Target Address				
Index1	Index2	Index3	Index4	
Address1				
Address2				
Address3				
Address4				

Figure 2: The ROUTE_REPLY packet used in DSR.

DSR: Data Packet

R	Option Length		Idetification
index1	index2	index3	index4
Address1			
Address2			
Address3			
Address4			

Figure 3: Format of data packet header in DSR. Duplicating the index and address fields, if necessary, can increase the route length by 4.

DSR: Error Packet

Type=ERROR	Option Length	Index
Originator Address		
From Hop Address		
Next Hop Address		

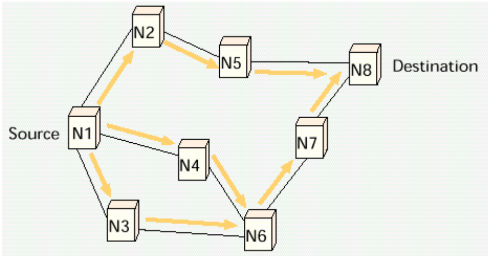
Figure 4: The ERROR packet used in DSR. The *originator address* field indicates the source of the data packet experiencing error, and the *from hop* and *next hop* addresses identify the two end nodes of the broken link.

AODV(Ad Hoc On-Demand Distance Vector)

AODV

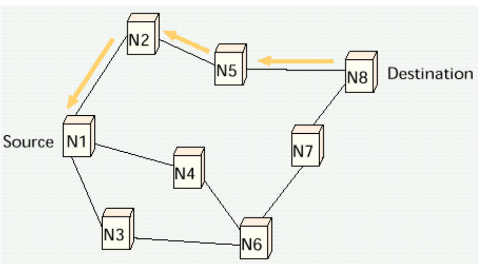
- Ad hoc On-demand Distance Vector
  - On-demand driven
  - Nodes that are not on the selected path do not maintain routing information
  - Route discovery
    - The source node broadcasts a route request packet (RREQ)
    - The destination or an intermediate node with “fresh enough” route to the destination replies a route reply packet (RREP)

AODV



(a) Propagation of the RREQ

AODV (cont.)



(b) Path of the RREP to the source

AODV: Route Request

Type	Reserved	Hop Count
Broadcast ID		
Destination IP address		
Destination Sequence Number		
Source IP address		
Source Sequence Number		

Figure 8: The ROUTE_REQ packet useds in AODV.

AODV: Route Reply

Type	L	Reserved	Hop Count
Destination IP address			
Destination Sequence Number			
Lifetime			

Figure 9: The ROUTE_REPLY packet used in AODV.

AODV

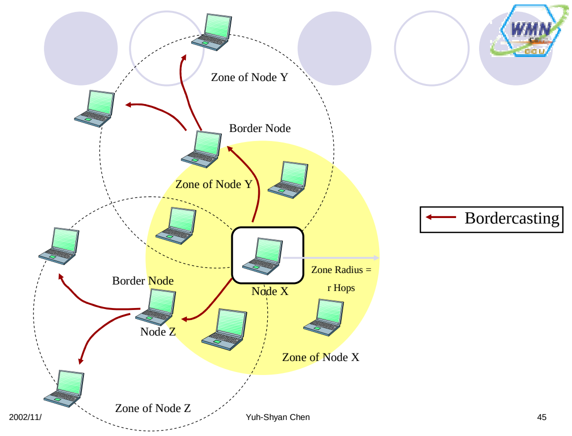
- Problem
  - A node along the route moves
- Solution
  - Upstream neighbor notices the move
  - Propagates a link failure notification message to each of its active upstream neighbors
  - The source node receives the message and re-initiate route discovery

ZRP(Zone Routing Protocol)-

Combining Pro-active and Reactive

ZRP

- Zone Routing Protocol
  - Hybrid protocol
    - On-demand
    - Proactive
  - ZRP has three sub-protocols
    - Intrazone Routing Protocol (IARP)
    - Interzone Routing Protocol (IERP)
    - Bordercast Resolution Protocol (BRP)



ZRP

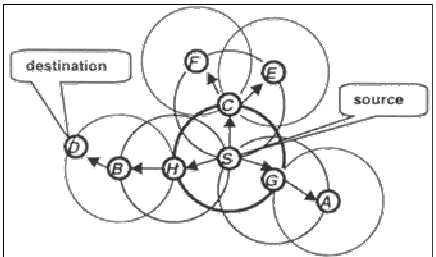
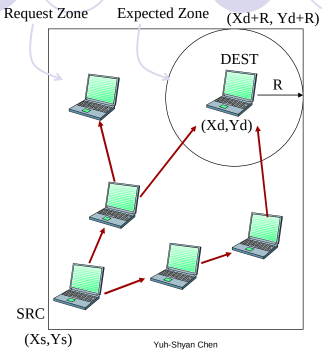


Figure 3: An example of the ZRP protocol

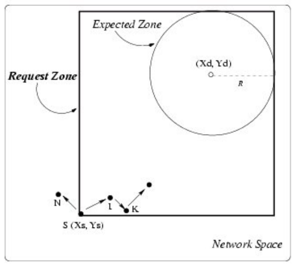
Location-Aware Routing (1) LAR

LAR

- Location-Aided Routing [Mobicom'98 best paper award]
  - Location information via GPS
  - Shortcoming
    - GPS availability is not yet worldwide
    - Position information come with deviation

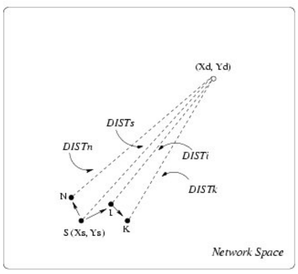


LAR



(a) LAR scheme 1

LAR(cont.)



(b) LAR scheme 2

Notebook + GPS

SSA(Signal Stability-Based Adaptive Routing)

SSA

Host	Signal Strength	Last	Clicks	Set
Y				
Z				

Table 2: The Signal Stability Table (SST)

Destination	Next Hop
Y	
Z	

Table 3: The Routing Table (RT)

SSA(cont.)

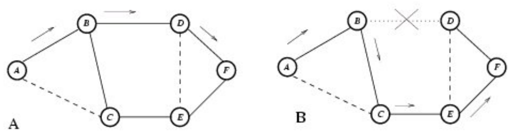
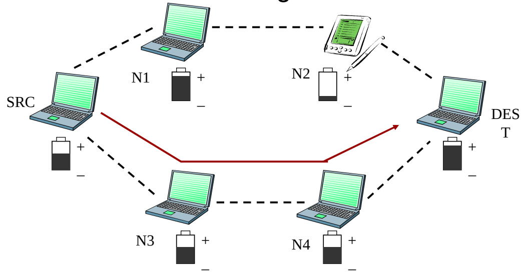


Figure 1: An Example Network

Power-Aware Routing

PAR

- Power-Aware Routing



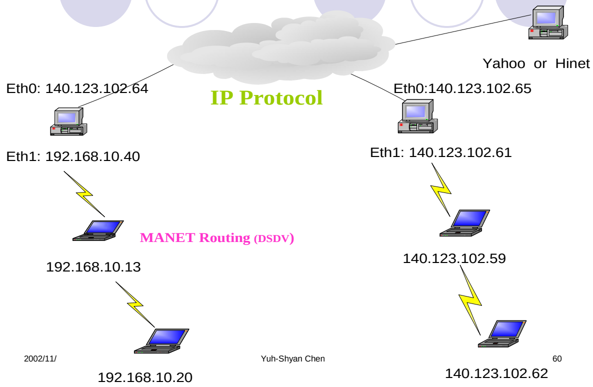
Mobile Ad-hoc Networks (manet) Working Group

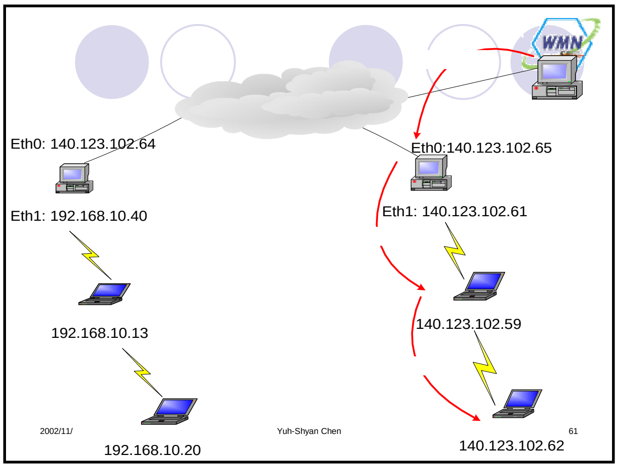
- Internet-Drafts: (http://www.cs.ccu.edu.tw/~yschen/course/92-1/wireless-92.html)

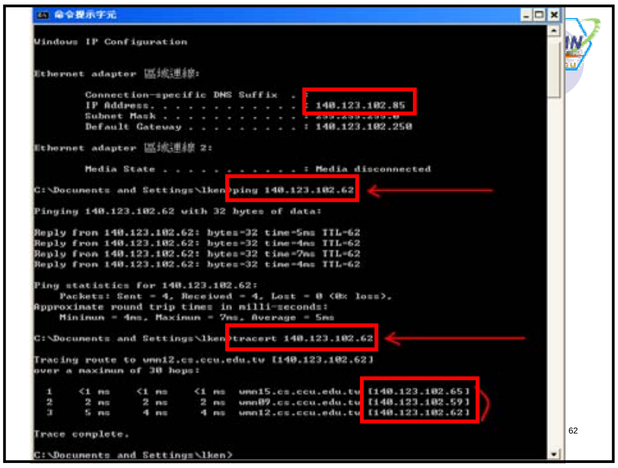
The Zone Routing Protocol (ZRP) for Ad Hoc Networks (38377 bytes)
Ad Hoc On Demand Distance Vector (AODV) Routing (84395 bytes)
The Dynamic Source Routing Protocol for Mobile Ad Hoc Networks (192667 bytes)
On-Demand Multicast Routing Protocol (ODMRP) for Ad-Hoc Networks (59372 bytes)
Topology Broadcast based on Reverse-Path Forwarding (TBRPF) (112739 bytes)
Landmark Routing Protocol (LANMAR) for Large Scale Ad Hoc Networks (50155 bytes)
Fisheye State Routing Protocol (FSR) for Ad Hoc Networks (38463 bytes)
The Interzone Routing Protocol (IERP) for Ad Hoc Networks (40534 bytes)
The Intrazone Routing Protocol (IARP) for Ad Hoc Networks (32486 bytes)
The Bordercast Resolution Protocol (BRP) for Ad Hoc Networks (35570 bytes)

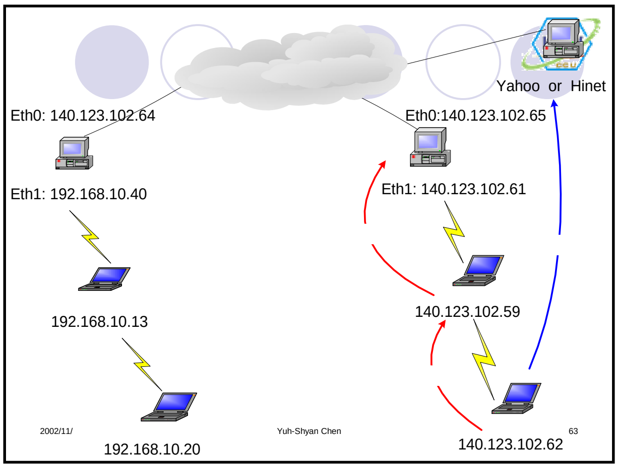
Wireless and Mobile Network Lab. 所設計的 MANET System

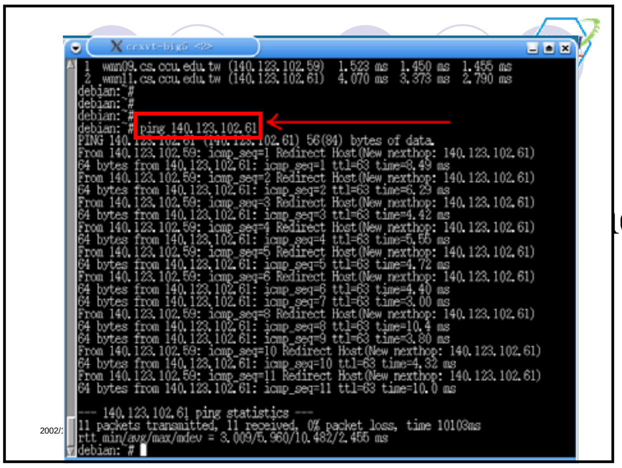
Current Results (IPv4 Multi-hop)









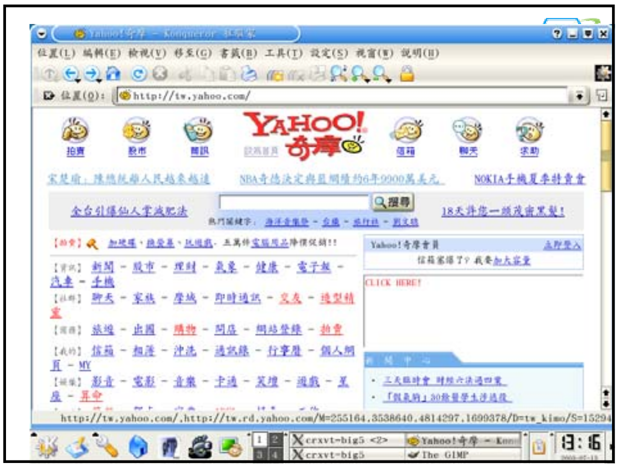


et v4

Router2

Ping I

MN4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