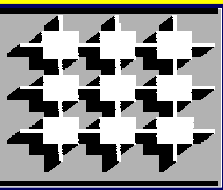
DIMACS

Center for Discrete Mathematics & Theoretical Computer Science
Founded as a National Science Foundation Science and Technology Center



The Challenges of Multicasting over Ad Hoc Mobile Wireless Networks

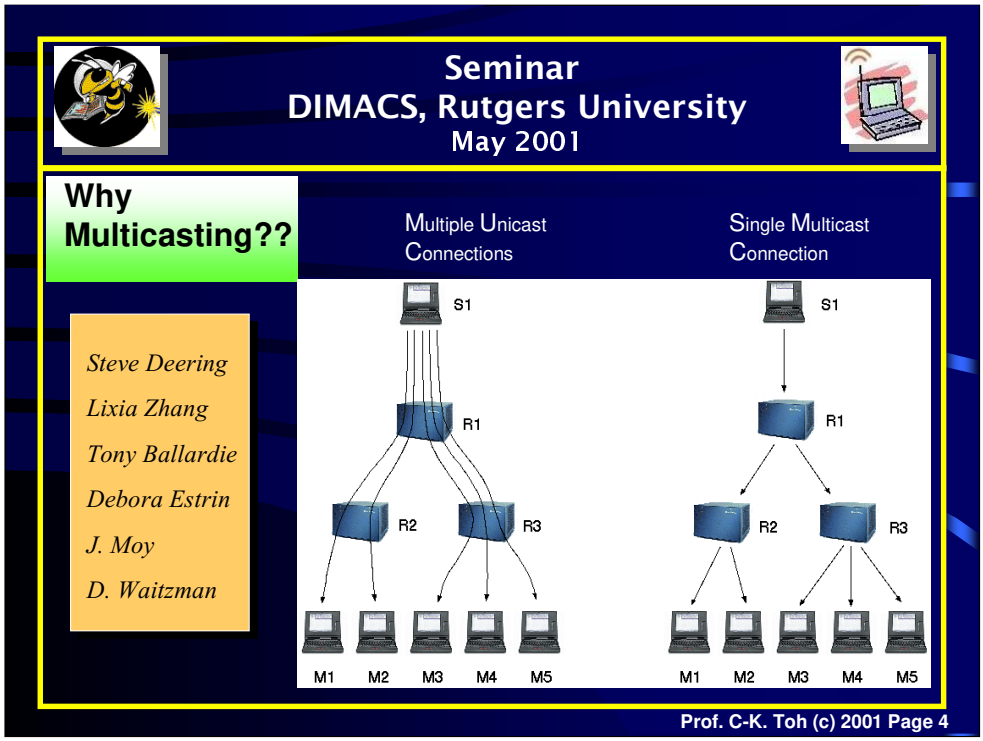
Prof. C-K. Toh
Chairman, IEEE TCPC Subcommittee on Ad Hoc Mobile Wireless Networks
Director, Ad Hoc Wireless Networking Consortium
Georgia Institute of Technology

Seminar
DIMACS, Rutgers University
May 2001

OUTLINE OF TALK

1. Why Multicasting ?
2. Wired Multicast
3. Wireless Multicast
4. Challenges
5. Ad Hoc Multicasting
6. Conclusion

Seminar
DIMACS, Rutgers University
May 2001
1
PART 1
Why Multicasting?
Prof. C-K. Toh (c) 2001 Page 3


Seminar
DIMACS, Rutgers University
May 2001
Why Multicasting??
Steve Deering
Lixia Zhang
Tony Ballardie
Debora Estrin
J. Moy
D. Waitzman
Multiple Unicast Connections
Single Multicast Connection
S1
R1
R2
R3
M1
M2
M3
M4
M5
Prof. C-K. Toh (c) 2001 Page 4

Seminar
DIMACS, Rutgers University
May 2001

Why Multicasting for Wireless?

- Communications over wireless devices are gaining in popularity
- Networked Video/Audio Conferencing is gaining in popularity (Vic, Vat, Sdr, ..)

Need to re-examine multicast approach for new next generation (NG) networks

Seminar
DIMACS, Rutgers University
May 2001
2
PART 2
Wired Multicasting
Prof. C-K. Toh (c) 2001 Page 6

Principles of IP Multicasting

IP addresses broken into classes:

Class A:
0.0.0.0 to 127.255.255.255
Class B:
128.0.0.0 to 191.255.255.255
Class C:
192.0.0.0 to 223.255.255.255
Class D:
224.0.0.0 to 239.255.255.255

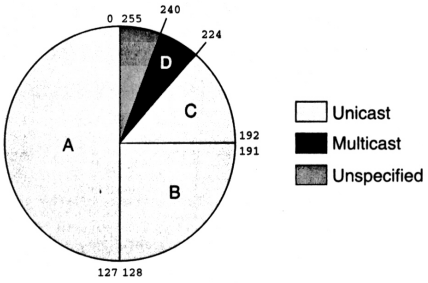
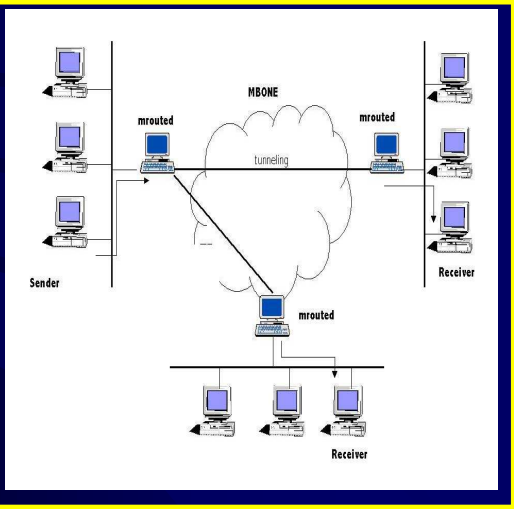


FIGURE 2–1 Complete IP address space

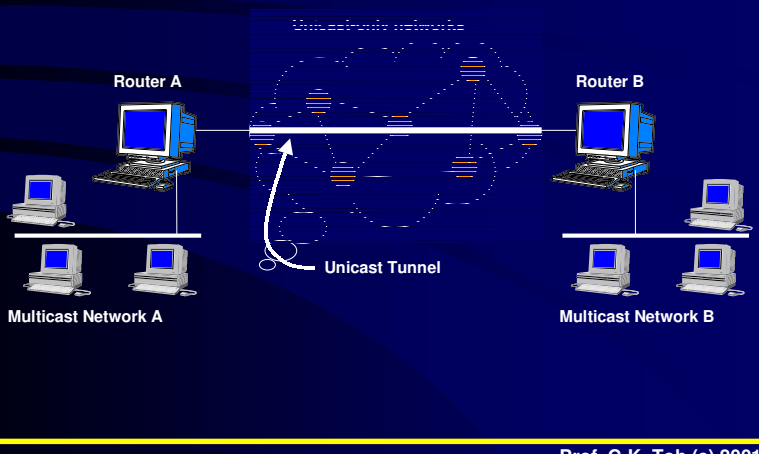
Principles of IP wired Multicasting

IP Multicast:

- Concept of Multicast ***addresses*** and ***groups***
- Example: DVMRP, MOSPF and PIM
- MBONE uses tunneling
- Source-based Shortest Path Multicast Trees
- ***Network Layer Multicast !***



Principles of IP Wired Multicasting



Principles of IP Multicasting

Tree : 1Root & Leaves and no loops

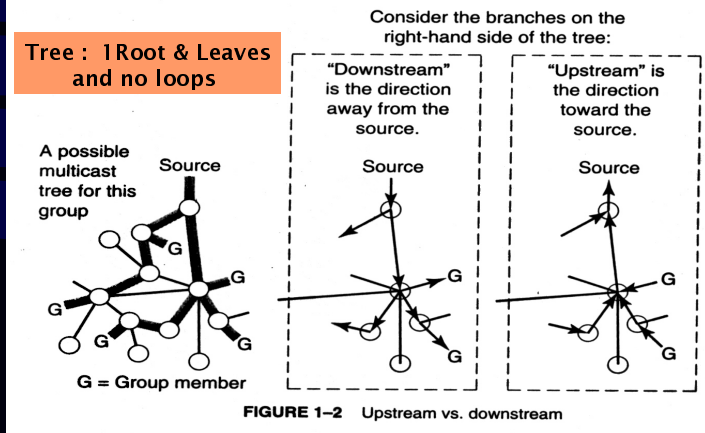
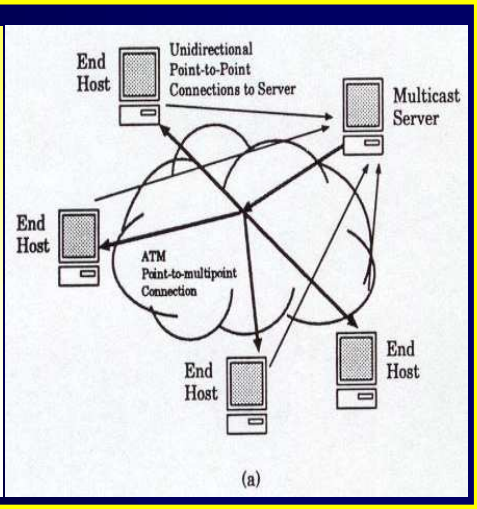


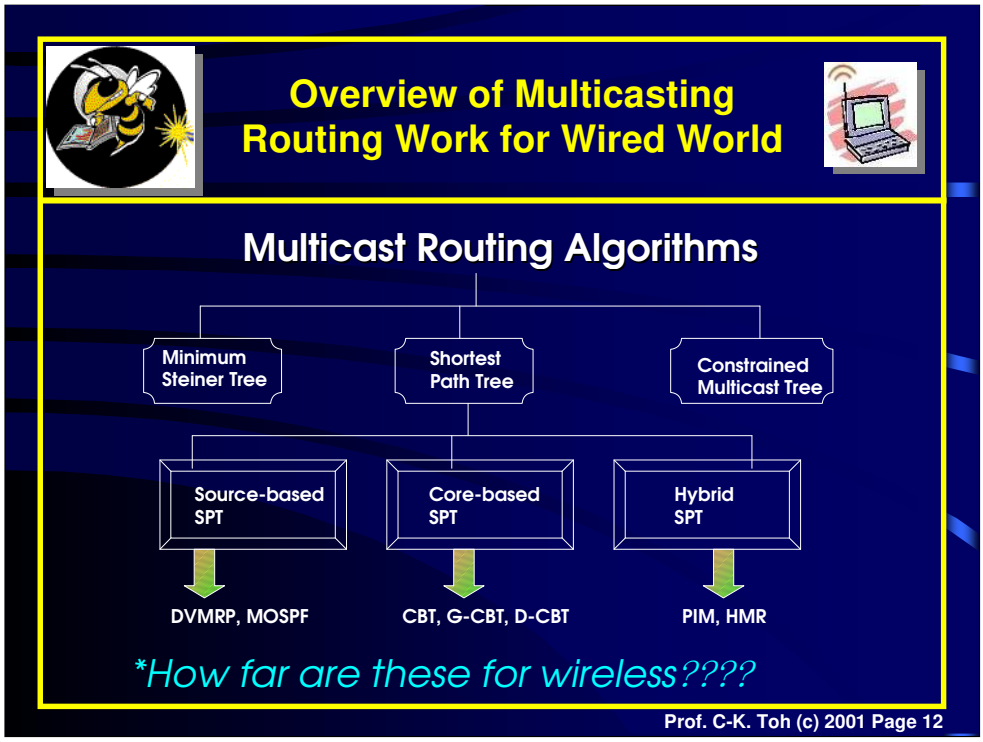
FIGURE 1–2 Upstream vs. downstream

Multicasting in Wired ATM Networks

Principles of ATM Multicasting

- Multiparty Connection Setup
- Establish point-to-multipoint Connections (Q.2971)
- Multicast Address Resolution (MC IP addresses to ATM addresses)
- ATM switch can support multicast at the ATM layer!
- Layer 2 Multicast



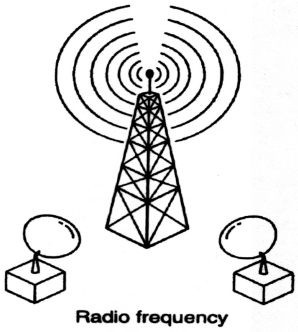

Overview of Multicasting Routing Work for Wired World
Multicast Routing Algorithms
Minimum Steiner Tree
Shortest Path Tree
Constrained Multicast Tree
Source-based SPT
Core-based SPT
Hybrid SPT
DVMRP, MOSPF
CBT, G-CBT, D-CBT
PIM, HMR
*How far are these for wireless????
Prof. C-K. Toh (c) 2001 Page 12

Seminar
DIMACS, Rutgers University
May 2001
3
PART 3
Wireless Multicasting

What about Wireless Multicasting??

Principles of Wireless Multicasting

Minimum Spanning Tree: A tree with route to all receivers with minimum total link cost !!



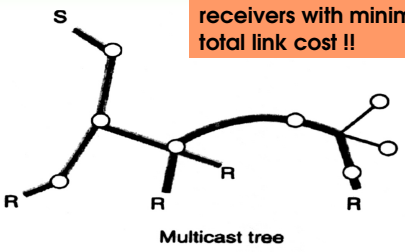


FIGURE 4–1 Multicast tree versus radio frequency

Wired vs Wireless MULTICASTING

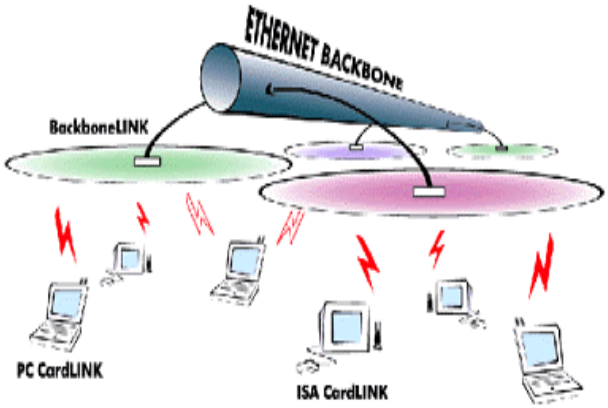
Principles of Multicasting

- Selective Broadcast
- Many receivers
- Single SRC
  + point-to-multipoint
- Many SRCs
  + multipoint-to-multipoint
- Multicast-enabled Routers
  + packet duplication
  + support multicast

Principles of Wireless Multicasting

- Wireless is broadcast in nature
- Problematic because of:
  + mobility of SRCs
  + mobility of DESTs
  + mobility of INs (nodes in tree!!!)
  + hidden terminal problems
  + MC group dynamics

Challenges
This (last-hop) versus .....

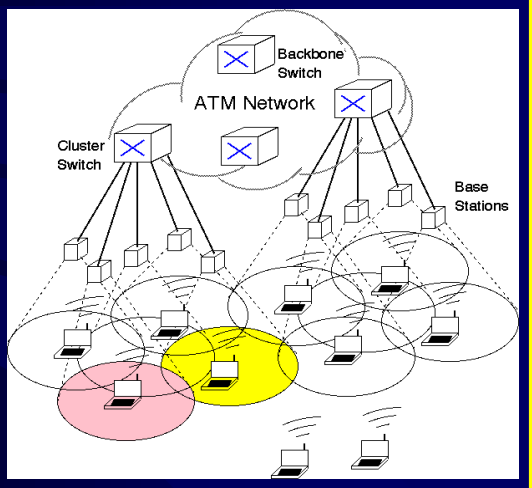


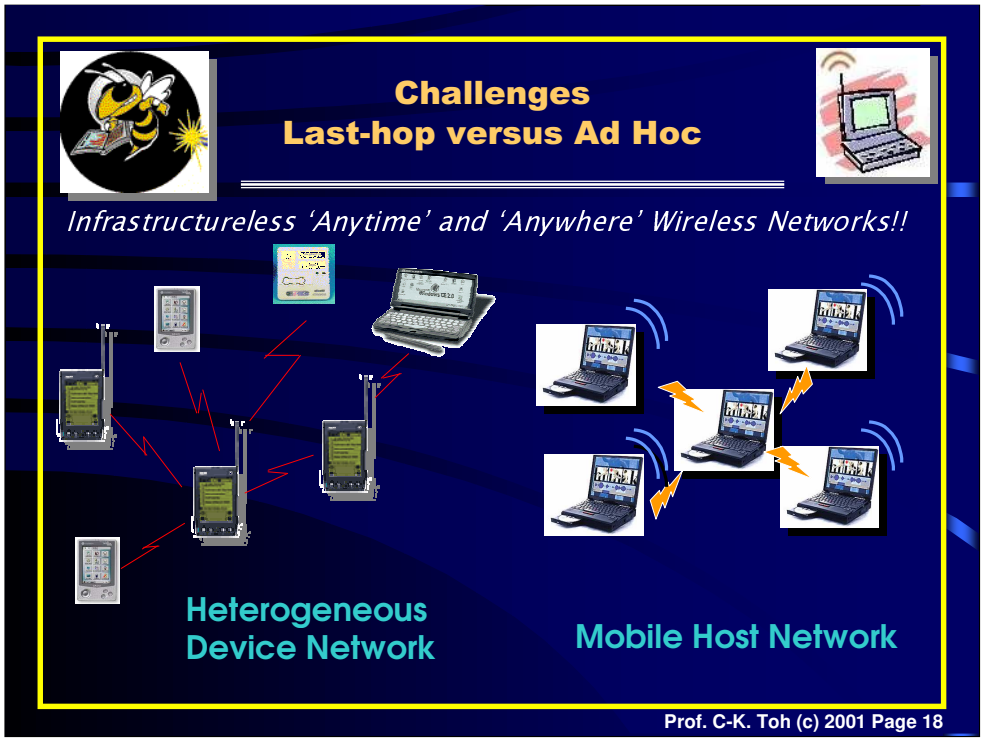
- Small Wireless Cell
- Base station-oriented
- Support Ethernet
- Mainly bridging
- Handoffs when crossing networks
- Uses Mobile IP

Challenges
Last-hop versus Ad Hoc

Characteristics

- Wireless last-hop
- Fixed Backbone Network
- Radio Base Stations
- Wireless Access
- Mobility Support
- Location Management
- Tied down to place and time
- Examples: CDPD, GSM, etc.,




Challenges
Last-hop versus Ad Hoc
Infrastructureless 'Anytime' and 'Anywhere' Wireless Networks!!
Heterogeneous
Device Network
Mobile Host Network
Prof. C-K. Toh (c) 2001 Page 18

What is an Ad Hoc Wireless Network?

Ad Hoc Capabilities & Concerns

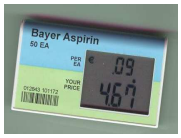
Active Badge

Window CE Palmtop

HP Palm Pilot

Laptop

3Com Palm Pilot



E-tag

- CPU
- Memory
- File Systems
- OS
- Display
- Power
- Comms
- HCI

So What are Specific Challenges??

- Mobility of tree nodes, source, and receivers
- Dynamically changing topology
- Asymmetric wireless links !
- Presence of Heterogeneous devices/nodes
- Power constraints
- Bandwidth constraints
- Computation constraints
- Display constraints
- Memory constraints
- All links in multicast path could be wireless!!!!

So what happens to traditional procedures??

- How to establish tree?
- Can we still use "broadcast-and-prune" approach?
- Can we still use IGMP for group membership management?
- Can we still handle dynamic group memberships?
- Can we still work with scalability issues (as in CBT)?
- Can we multicast wireless audio and video in ad hoc?
- How about some form of QoS for ad hoc wireless multicast?

Seminar
DIMACS, Rutgers University
May 2001
4
PART 4
Current Approaches to Wireless Ad Hoc Multicasting

Unicast Routing Research: How far have we gone??

ROUTING

Edsger Wybe Dijkstra (ACM Turing Award, 1972)
Professor Emeriti, University of Texas at Austin

Shortest Path Algorithm from Dijkstra widely used in routing in wired networks today!

Question:

How good is shortest path for routing in mobile ad hoc networks ??

Where is the breakthrough in today's routing work?

New Unicast Routing Protocol for Ad Hoc Wireless Networks

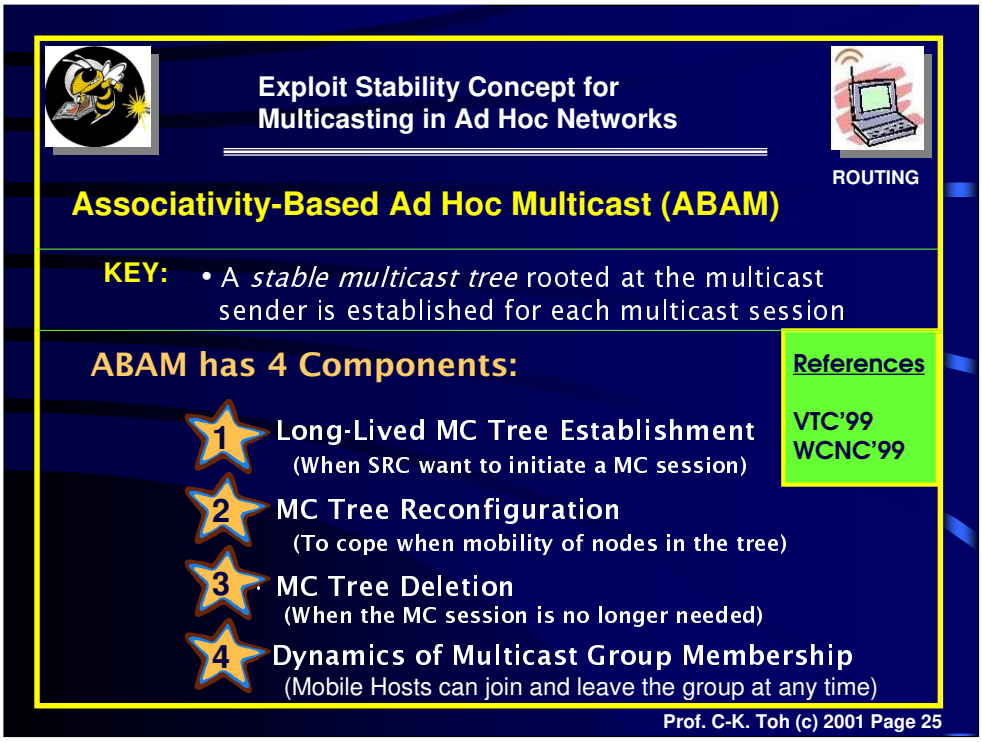
ROUTING

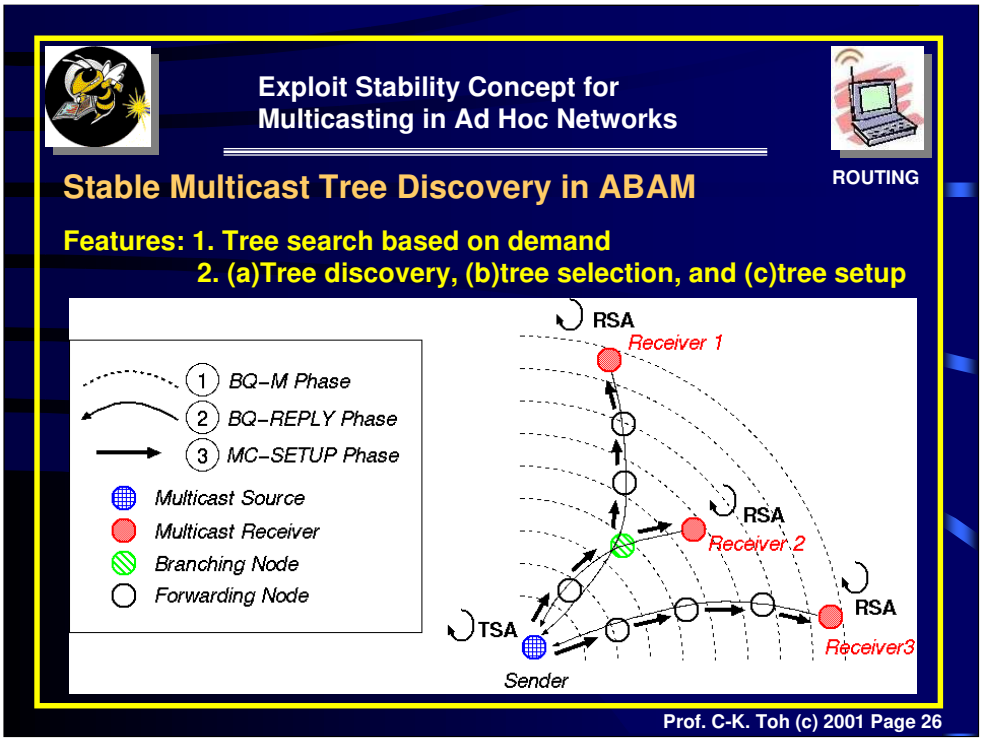
- Long-lived Routing is a breakthrough from the traditional shortest path routing paradigm!

- Stability - Connection, power, signal, link/route, temporal, spatial
- On-demand Source-Initiated Routing

Remark:

Why bother to choose a shortest path route if this route is going to be unstable!


Exploit Stability Concept for
Multicasting in Ad Hoc Networks
ROUTING
Associativity-Based Ad Hoc Multicast (ABAM)
KEY: • A stable multicast tree rooted at the multicast sender is established for each multicast session
ABAM has 4 Components:
References
VTC'99
WCNC'99
1 Long-Lived MC Tree Establishment
(When SRC want to initiate a MC session)
2 MC Tree Reconfiguration
(To cope when mobility of nodes in the tree)
3 MC Tree Deletion
(When the MC session is no longer needed)
4 Dynamics of Multicast Group Membership
(Mobile Hosts can join and leave the group at any time)
Prof. C-K. Toh (c) 2001 Page 25

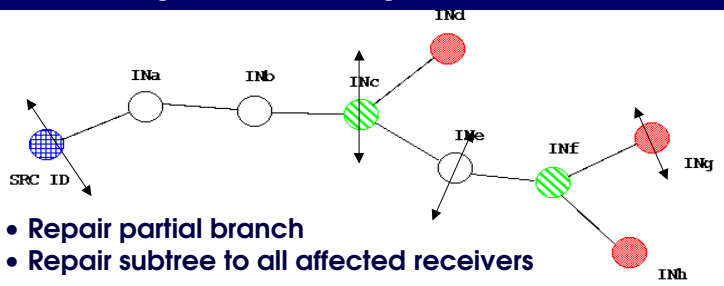

Exploit Stability Concept for
Multicasting in Ad Hoc Networks
ROUTING
Stable Multicast Tree Discovery in ABAM
Features: 1. Tree search based on demand
2. (a)Tree discovery, (b)tree selection, and (c)tree setup
1 BQ–M Phase
2 BQ–REPLY Phase
3 MC–SETUP Phase
Multicast Source
Multicast Receiver
Branching Node
Forwarding Node
RSA
Receiver 1
RSA
Receiver 2
RSA
Receiver3
TSA
Sender
Prof. C-K. Toh (c) 2001 Page 26

Exploit Stability Concept for
Multicasting in Ad Hoc Networks

ROUTING

Route Reconfiguration in ABAM

Repair{Originator, Route ID, Ref from SRC} **or**
Repair{Originator, Route ID, Time of Event} **or**
Redo{SRC ID, Route ID}

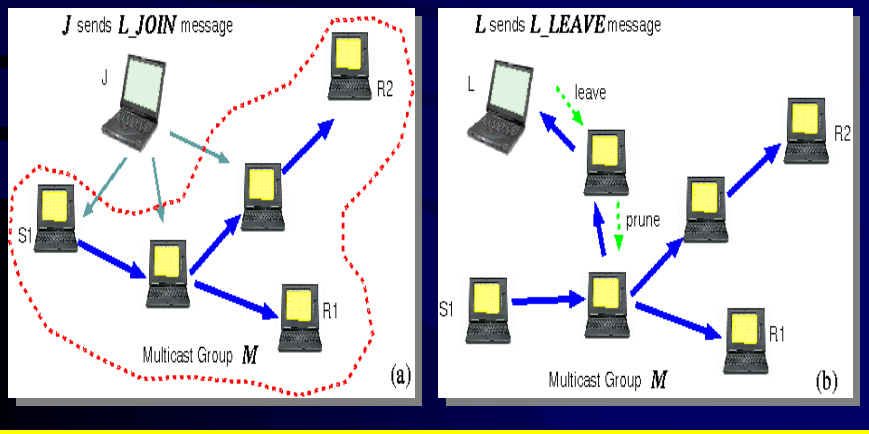


- Repair partial branch
- Repair subtree to all affected receivers

Exploit Stability Concept for Multicasting in Ad Hoc Networks

ROUTING

Membership Dynamics in ABAM

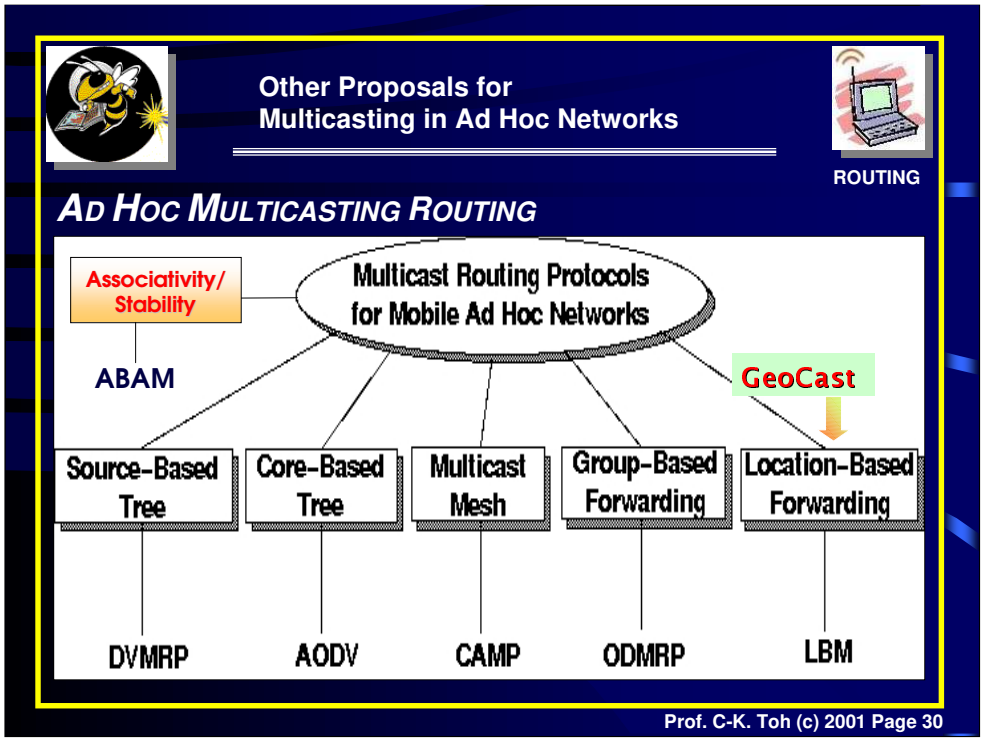


Exploit Stability Concept for Multicasting in Ad Hoc Networks

ROUTING

Tree Deletion in ABAM

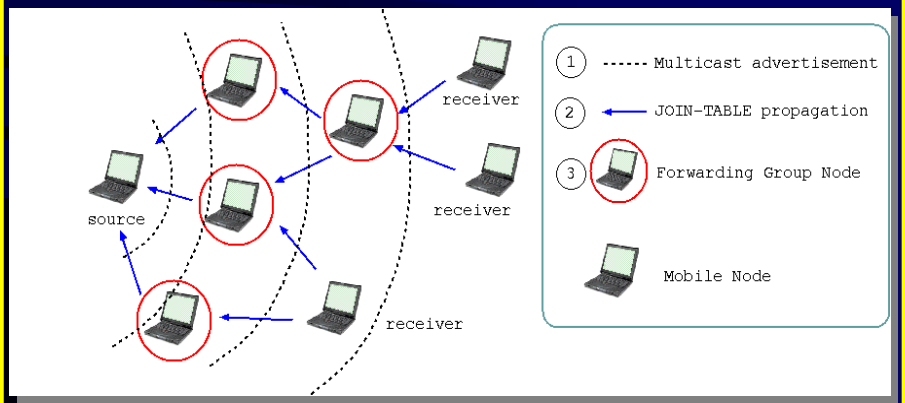
- Case when there are no more Receivers
  - Each departing receiver prunes its branch
  - Eventually, the tree is pruned completely
- Case when sender stops acting as Multicast source
  - Sender broadcast tree delete message
  - Receiver and Tree nodes remove their roles


Other Proposals for
Multicasting in Ad Hoc Networks
ROUTING
AD HOC MULTICASTING ROUTING
Multicast Routing Protocols
for Mobile Ad Hoc Networks
Associativity/
Stability
ABAM
GeoCast
Source-Based
Tree
Core-Based
Tree
Multicast
Mesh
Group-Based
Forwarding
Location-Based
Forwarding
DVMRP
AODV
CAMP
ODMRP
LBM
Prof. C-K. Toh (c) 2001 Page 30

Other Proposals for
Multicasting in Ad Hoc Networks

ROUTING

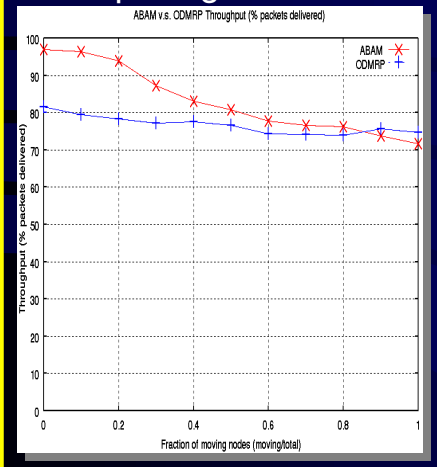
Comparing ABAM with UCLA (Mario Gerla)
ODMRP (Flooding-Based)

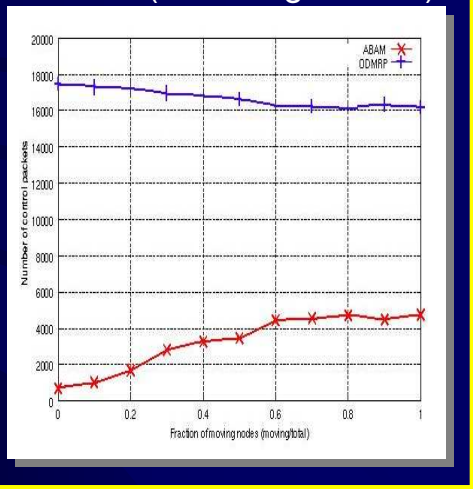


Other Proposals for Multicasting in Ad Hoc Networks

GLOMOSIM

Comparing ABAM with ODMRP (Flooding-Based)

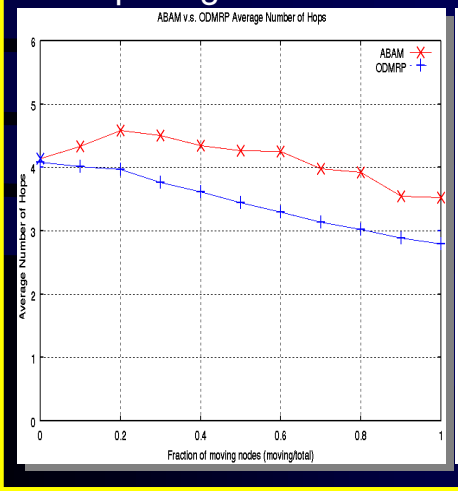


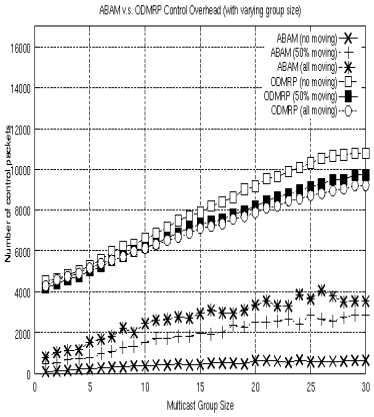


Other Proposals for Multicasting in Ad Hoc Networks

GLOMOSIM

Comparing ABAM with ODMRP (Flooding-Based)



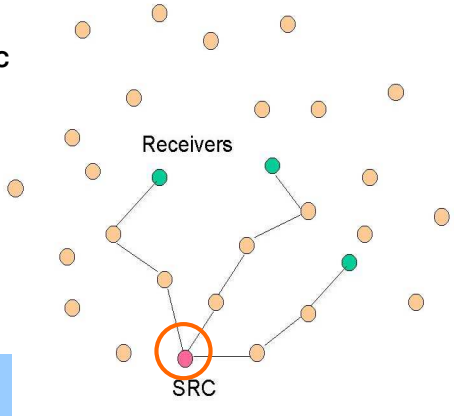


Other Proposals for Multicasting in Ad Hoc Networks

SOURCE-BASED MULTICAST

Basic Principles

- Multicast tree rooted at SRC
- SRC runs a multicast tree algorithm
- SRC may need topology info & receivers addr to derive multicast tree.
- Examples:
  - + MOSPF
  - + DVMRP
- Disadvantages:
  - + Not scalable
  - + Not efficient
- A MC tree is established per source group pair.

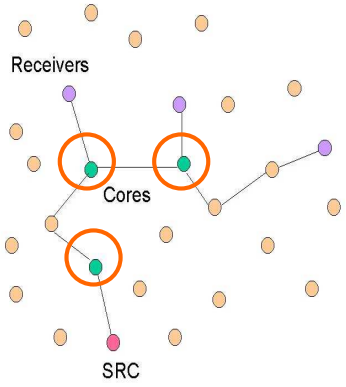


Other Proposals for Multicasting in Ad Hoc Networks

CORE-BASED MULTICAST

Basic Principles

- Multicast tree originated from the core ! ! !
- More than 1 core could exist
- Need ***core selection algorithm*** (so far not many concrete ones)
- Resultant tree may not be optimal
- Core nodes can be interconnected via bi-directional links
- Receiver-initiated join
- Examples:
  - + CBT (Core-Based Trees)
- A single MC tree is formed for each MC group

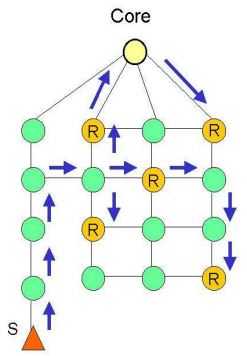


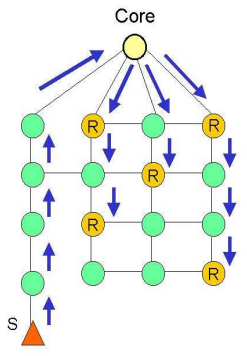
Other Proposals for Multicasting in Ad Hoc Networks

CORE-Assisted MULTICAST (J.J. UC Santa Cruz)

Basic Principles

- What is a mesh??
- Nodes are interconnected to multiple nodes (not star or bus topology)
- Why mesh??
- Alternate path available.
- Restrictions:::
- Requires some background operation to keep mesh alive..

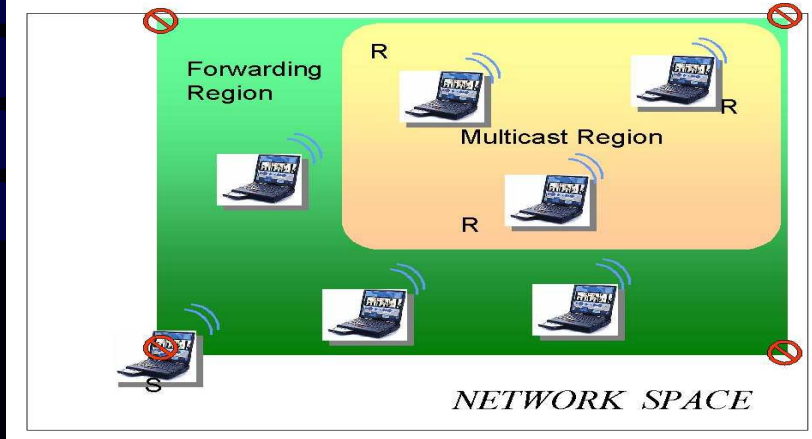




CAMP Versus Core-Based Tree

Other Proposals for Multicasting in Ad Hoc Networks

Location-Aided Multicast (GEOcast)



Other Proposals for Multicasting in Ad Hoc Networks

Location-Aided Multicast (GEOcast)

Shortcomings of LAM Scheme

- Assumes every node knows its location information ??
- Multicast members must reside in multicast region (confined??)
- Nodes in the Multicast region must not be partitioned in terms of connectivity
- Forwarding region must cover multicast region otherwise members will not receive multicast packets
- Requires positional information of boundary nodes of forwarding region
- Does not take into account of signal quality and connecitivity.
- Exist case when request packet cannot reach receivers due to position restrictions

Seminar
DIMACS, Rutgers University
May 2001
5
PART 5
Concluding Remarks

Seminar
DIMACS, Rutgers University
May 2001

Conclusion

Many remaining issues present for research:

- Issues of Asymmetric Links
- Power/Bandwidth Efficient & Scalable Multicast
- Issues of Multicast QoS & Pricing
- Multicast Interoperability & Performance
- Multicast with Smart Antennas
- Reliance on underlying unicast routing protocol
- Active Reliable Wireless Multicast
- Content-Based Multicast

Contact:

- Prof. C-K. Toh
- Email: cktoh@ece.gatech.edu

Bye. Ciao. Merci

Seminar
DIMACS, Rutgers University
May 2001

Many remaining issues present for research:

*** Panel ***

- Issues of Asymmetric Links
- Power/Bandwidth Efficient & Scalable Multicast
- Issues of Multicast QoS & Pricing
- Multicast Interoperability
  - Asymmetric Pipe
  - Different networks using different multicast protocols
- Multicast Performance (Layer 1 & 2 Multicast)
- Multicast with Smart Antennas
- Reliance on underlying unicast routing protocol
- Reliable Wireless Multicast
- Content-Based Multicast
- Active Multicast
- How pervasive is multicast commercially?

NICK

Inclusion of time and probablistic info into multicast to support Multicast QoS

Bluetooth is dead - 802.11 chips @$3.

Michalis

Multicasting does not scale.

ISP does not support multicast.

Internet TV, distributed games; music,

Advice for students on MC research

Ad Hoc Multicast