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Norway/Sweden/Finland

IEEE

Future Research Challenges for Ad Hoc Mobile Wireless Networks

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1. **Views expressed in this presentation are solely from the speaker. It does not represent collective view of IEEE nor TRW.**

2. **For students – this might be good time to pick a topic for research.**

3. **For professors – this might be a good time to consider writing research proposals to fund new topics**

4. **Please cite references/origin of this talk/seminar should you must to use the ideas introduced here.**

Outline Of Talk

- Ad hoc mobile networks
- Current research
- Future research
- Conclusion

Talk tends to be more philosophical than result-oriented……

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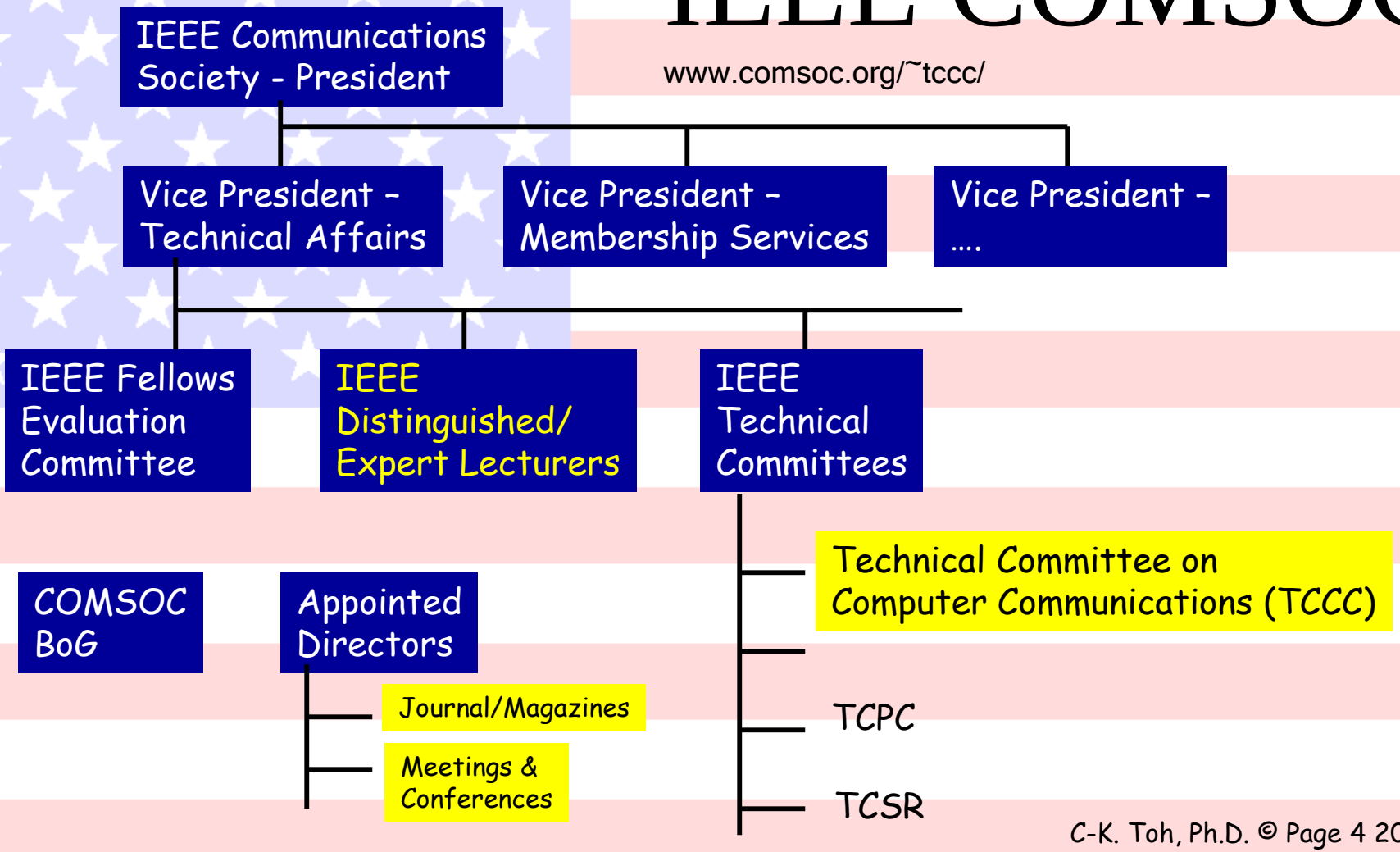

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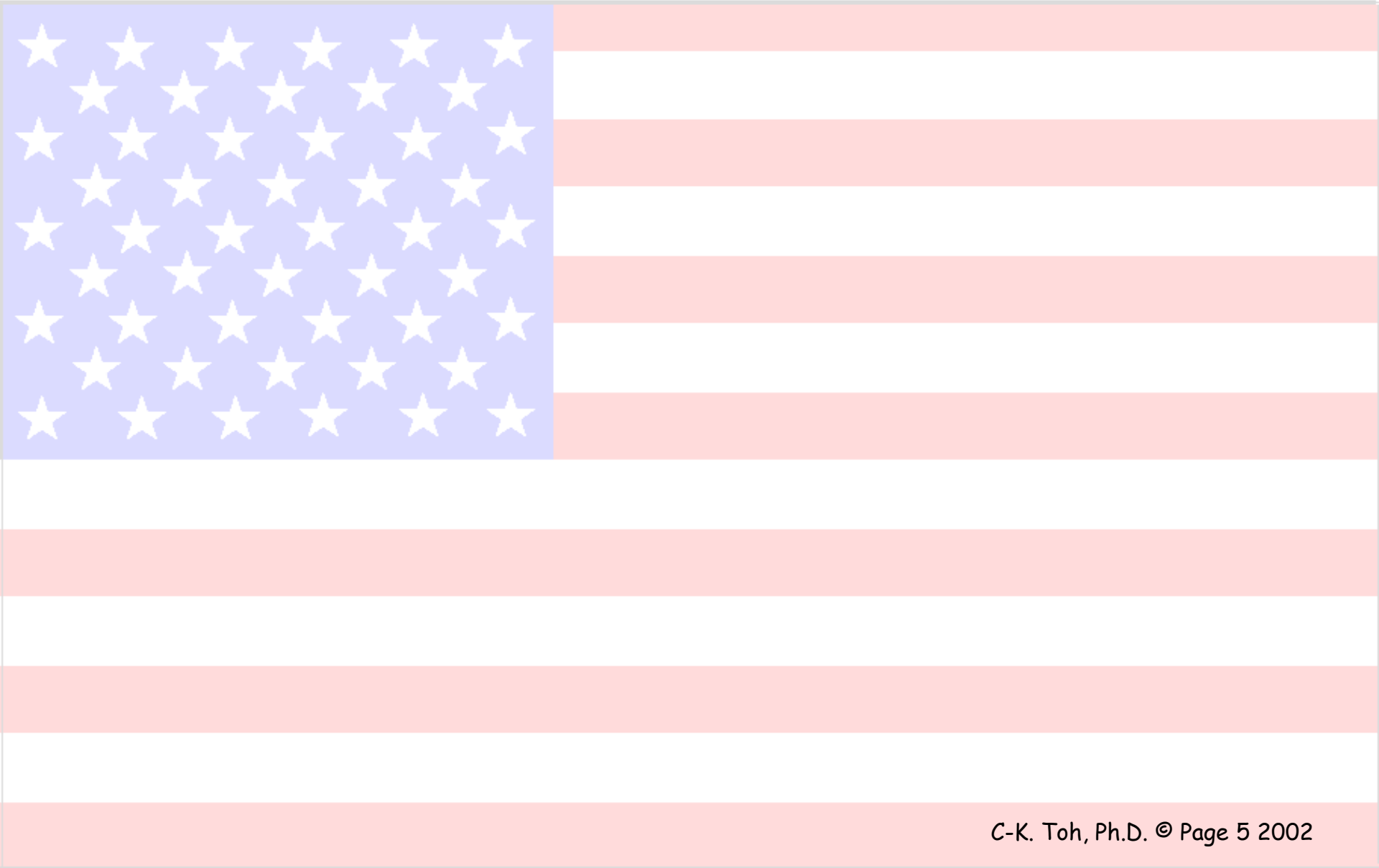


Started Ad Hoc Research since 1993 Cambridge University

Some earlier computer pioneers.....

Issac Newton
Inventor of Calculus. Laws of Gravity. Optics.
(now gone..)

Alan Turner
Inventor of Turing Machine
(now gone..)

Maurice Wilkes
Inventor of Microprogramming
(now retired)

Andrew Hopper
Co-Inventor of Cambridge Ring
(professor at Cambridge Universty Engg. Dept)

David Tennenhouse
Inventor of Active/ Programmable Networks
(vice president, INTEL)

Swedes Achievers

Dynamite (1866)

Norwegian Achievers

Object-Oriented Programming

Ole-Johan Dahl (1978)

Kristen Nygaard (1978)

Finnish Achievers

Chemistry (1945)

Artturi Ilmari Virtanen

Finland

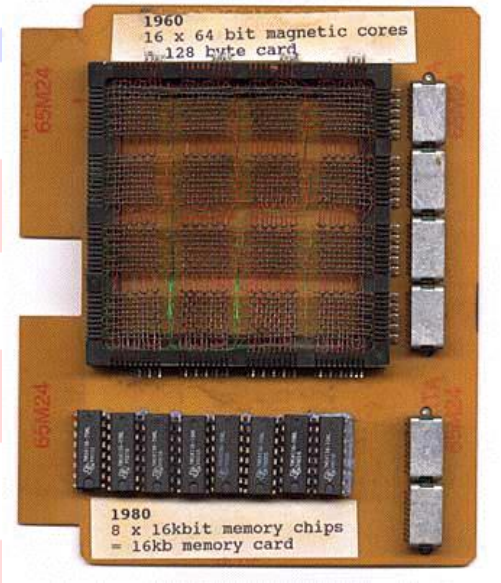
Helsinki University
Helsinki, Finland

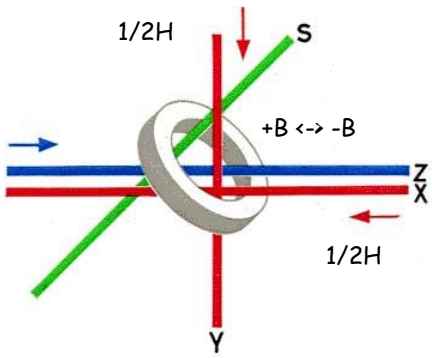
Ph.D. Harvard 1948
Born 1920
Died: Mar 1990

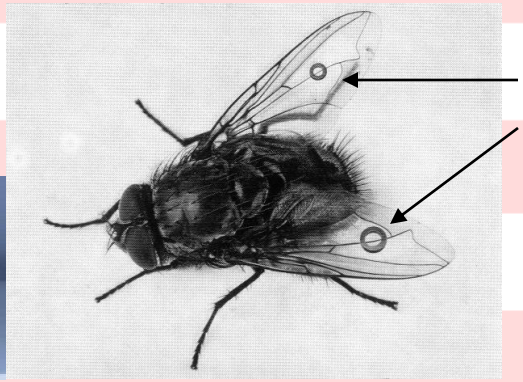
US Patent 2708722
"Pulse Transfer Controlling Device"

Founded Wang Laboratories in Boston, MA.

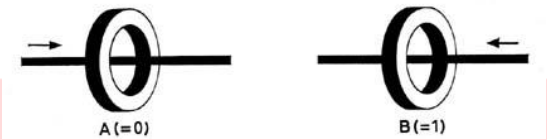
WANG



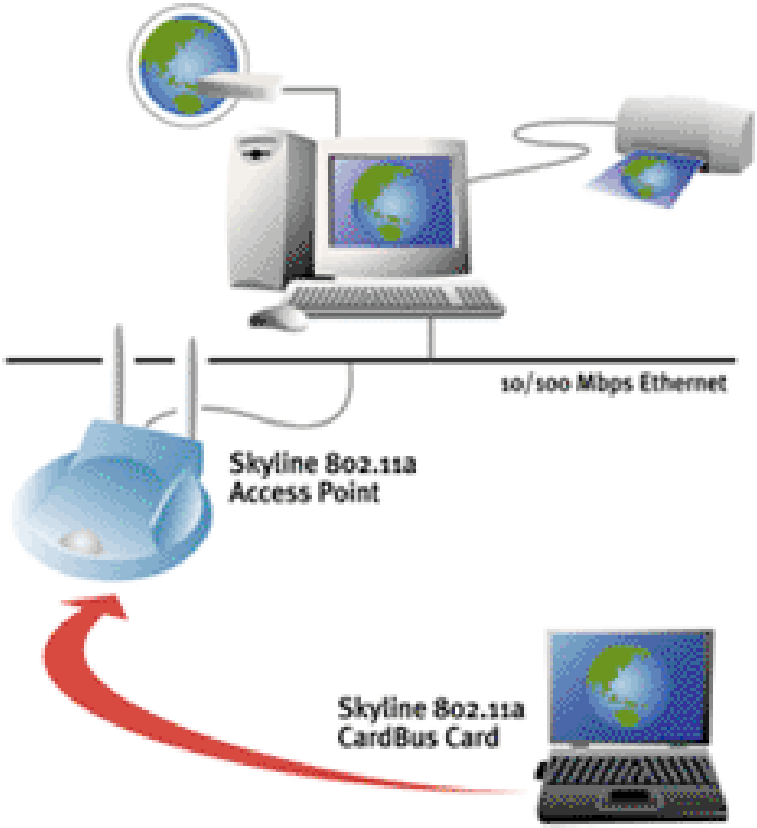


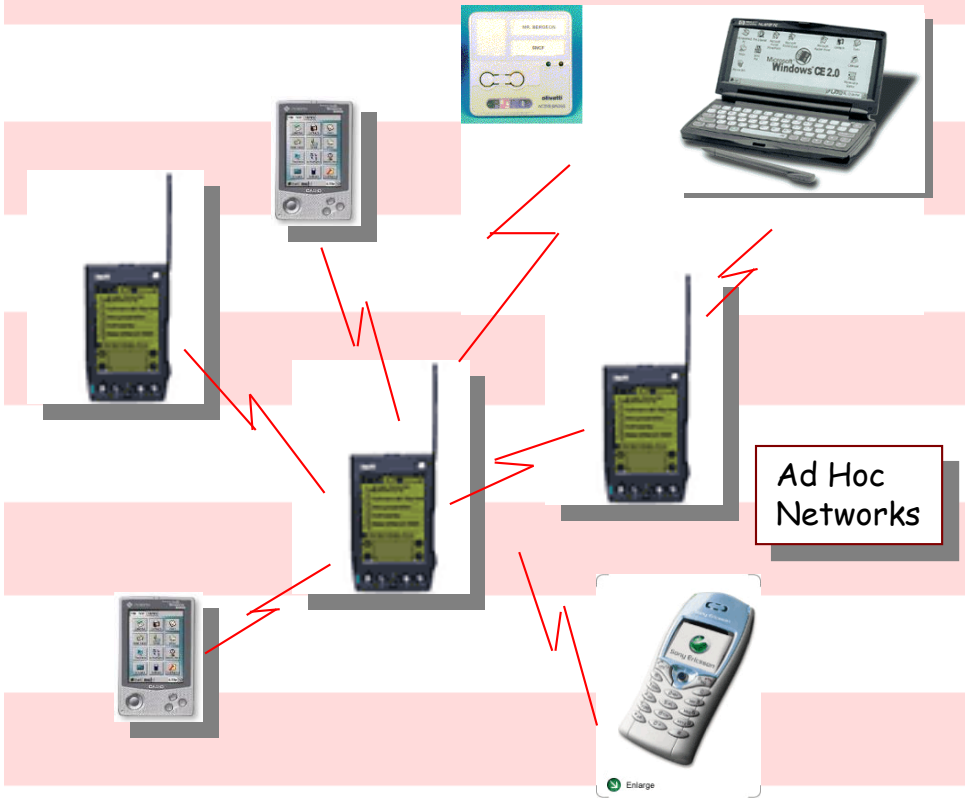


20-30 mil core



Today: A Shift In Access Paradigm





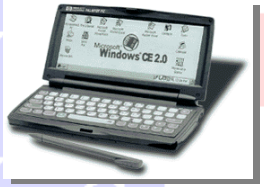
From this…….. To This!!

Today: A Shift In Network Paradigm

1. No Infrastructure
2. No fixed entities
3. "All-wireless" links
4. Mobility
5. Heterogeneity
6. Self-organizing
7. Self-maintaining
8. So,,, no telcos !!

Today: Proliferation Of Devices

Active Badge



Window CE Palmtop

Samsung NEXiO Wireless Hand PC

PDA

Wireless Camera

Laptop

3Com Palm Pilot

E-tag

Cell phone

Watch

E-paper

Differences
In construction
& capability

CPU
Memory
File Systems
OS
Display
Power
Comms
HDI

Current/Previous Research:

1. **Ad Hoc Unicast Routing; Power-aware routing**
2. **Ad Hoc Multicast Routing; Geocasting**
3. **Ad Hoc Media Protocols based on omni-radios**
4. **Ad Hoc TCP (Transmission Control Protocol)**
5. **Ad Hoc internetworking (gateways)**
6. **A bit on ad hoc network management**

1993
1994
1995
1996
1997
1998
1999
2000
2001
2002

Current: Limited Power Life

Problem Space 1:

1. **Advances in Processors far exceeds advances in battery technologies!!**

2. **Battery technologies hitting electro-chemical limits – impact uptime of mobile devices and hence mobile communications**

Rechargeables

Small Electronics

Energizer® e²™ Photo

Hearing Aids

Energizer® Max™

Energizer® e²™

Future: Integrated Power Management

Problem Space 2:

1. **Power conservation and management methods are very *fragmented* and *not leveraged* properly.**

2. **This gives rise to "improper" or *"ineffective" power management*, i.e., we are fooled into believing that we are using power efficiently…**

Future: Integrated Power Management

Correct Power View

Comms-Related

- Ethernet
- USB
- FDDI
- Wireless 802.11b
- IrDA

Non-comms related

- Keyboard
- Display
- Hard Disk Drive
- Floopy Drive
- Mouse, etc.

Future: Integrated Power Management

Comms-Related

P-E Hardware

P-E Software

Manager

PROTOCOL LAYER POWER CONSERVATIONS	
Data-link Layer	• Avoid unnecssary retransmissions; avoid collisions in channel access; • Put receiver in standby mode whenever possible; turn radio off when not Transmitting or receiving
Network Layer	• Consider route relaying load; consider battery life in route selection; power-Aware routing; reduce frequency of sending control messages; optimize or Compress control headers; efficient route repair techniques during mobility.
Transport Layer	• Avoid repeated retransmissions; • Handle packet loss in a localized manner; • Use power-efficient error control schemes; •

E per Bit

Future: High Capacity Wireless

Current wireless technologies – bandwidth scenarios

915 MHz

Aironet	860Kbps
Metricom	100Kbps
WaveLAN	2Mbps

2.4 GHz

Freeport	5.7Mbps
WaveLAN	2Mbps
AirLAN	10Mbps
WaveLAN Turbo	11Mbps

5.8 GHz **U-NII Band**

RadioLAN	10Mbps
WaveSpan	10Mbps
AirLAN	10Mbps
WaveLAN Turbo	11Mbps
Proxim Skyline	100Mbps



802.11a – 54Mbps – 5G
802.11b – 22Mbps – 2.4G WiFi
802.11e - QoS
802.11g – Higher Data Rate
802.11h – Spectrum Mgmt
802.11i – Enhanced Security

Future: High Capacity Ad Hoc

Problem Space 1:

1. **We are hitting pretty good bandwidth for WLANs**
2. **However, bandwidth for ad hoc wireless networks is still pretty stagnant..**

Q. Why we need high bandwidth for ad hoc??

1. **Too low bandwidth render ad hoc comms useless**
2. **Want to support multi-media traffic**

Future: High Capacity Ad Hoc

Questions about Bandwidth:

1. **Any real operational, commercial ad hoc wireless networks??**

2. **Second real issue is: bandwidth degrades with increasing multi-hop links …. (see next slide)**

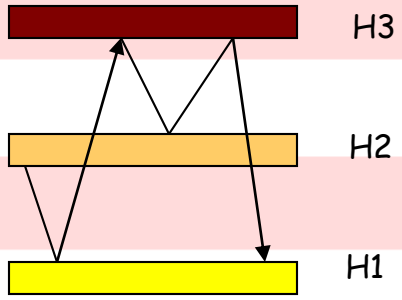
Bluetooth – 2Mbps

DSR testbed ??

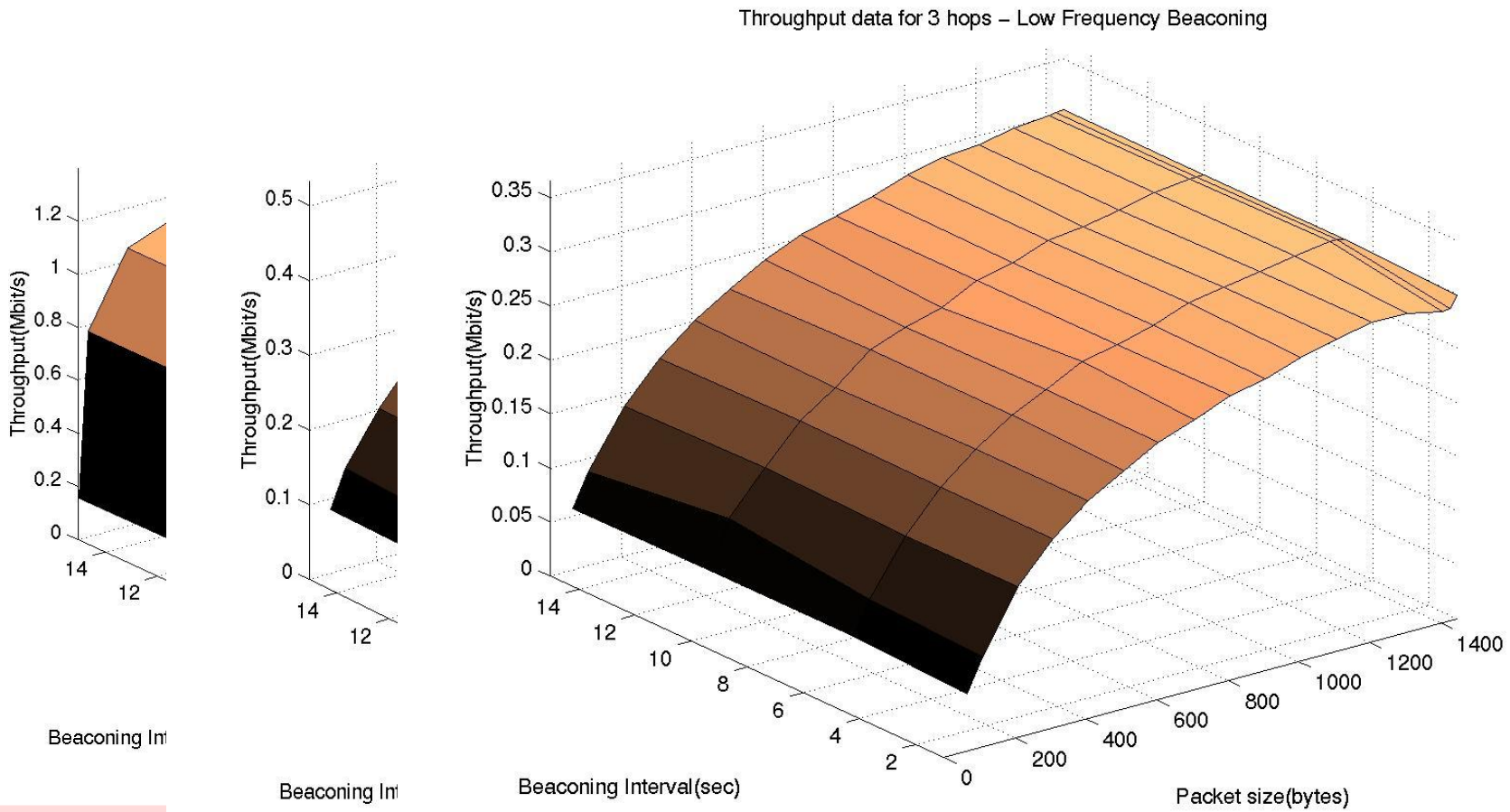
AoDV testbed ??

ABR testbed ??

Need "very fast forwarding" mechanism and High capacity radio links for ad hoc



DSR – Dynamic Source Routing
AODV – Ad Hoc Distance Vector
ABR – Associativity Based Routing



Source: "Evaluating the Communication Performance of an Ad Hoc Wireless Network", IEEE Transactions on Wireless Communications, Vol. 1, No. 3, JULY 2002.

Future: Providing High Capacity Ad Hoc

Q. How to achieve higher bandwidth??

1. **Improve on radio technologies – moving away from omni to directional/smart antennas**

2. **Improve on MAC protocol**

Combat asymmertic links, multipath fading, signal interferences, dead spots, hidden terminals, Use multiband Radios, Ultra-wideband Radio (UWB), SDR, etc.,

Combat asymmetric links, contention, less handshake, more transmission, less retransmission,

Future: Analysis Of Ad Hoc Capacity

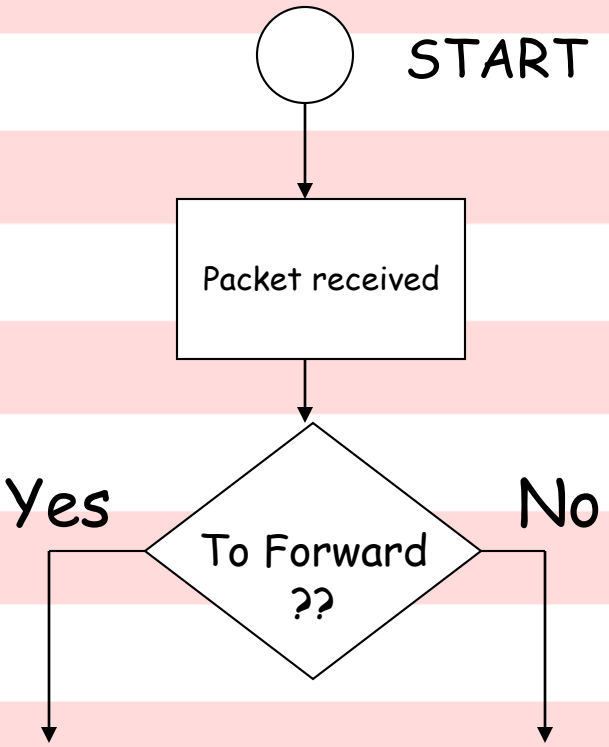
Aim: **Provide good theoretical analysis of ad hoc performance…**

1. **What is the impact of *neighbors* on per node comms and per route comms performance? *Interference impact* ?**
2. **What do we mean by *route relaying load* ?**
3. **How is "*route neighboring factor*" and "*node neighboring factor*" affecting communication performance?**
4. **What is *route length* impact on communication performance?**
5. **What is the bottleneck of a *single channel* ad hoc wireless system?**
6. **How is *queueing* and *relaying policy* affecting performance?**

Future: Forwarding Models & Incentives

Problem Space 1:

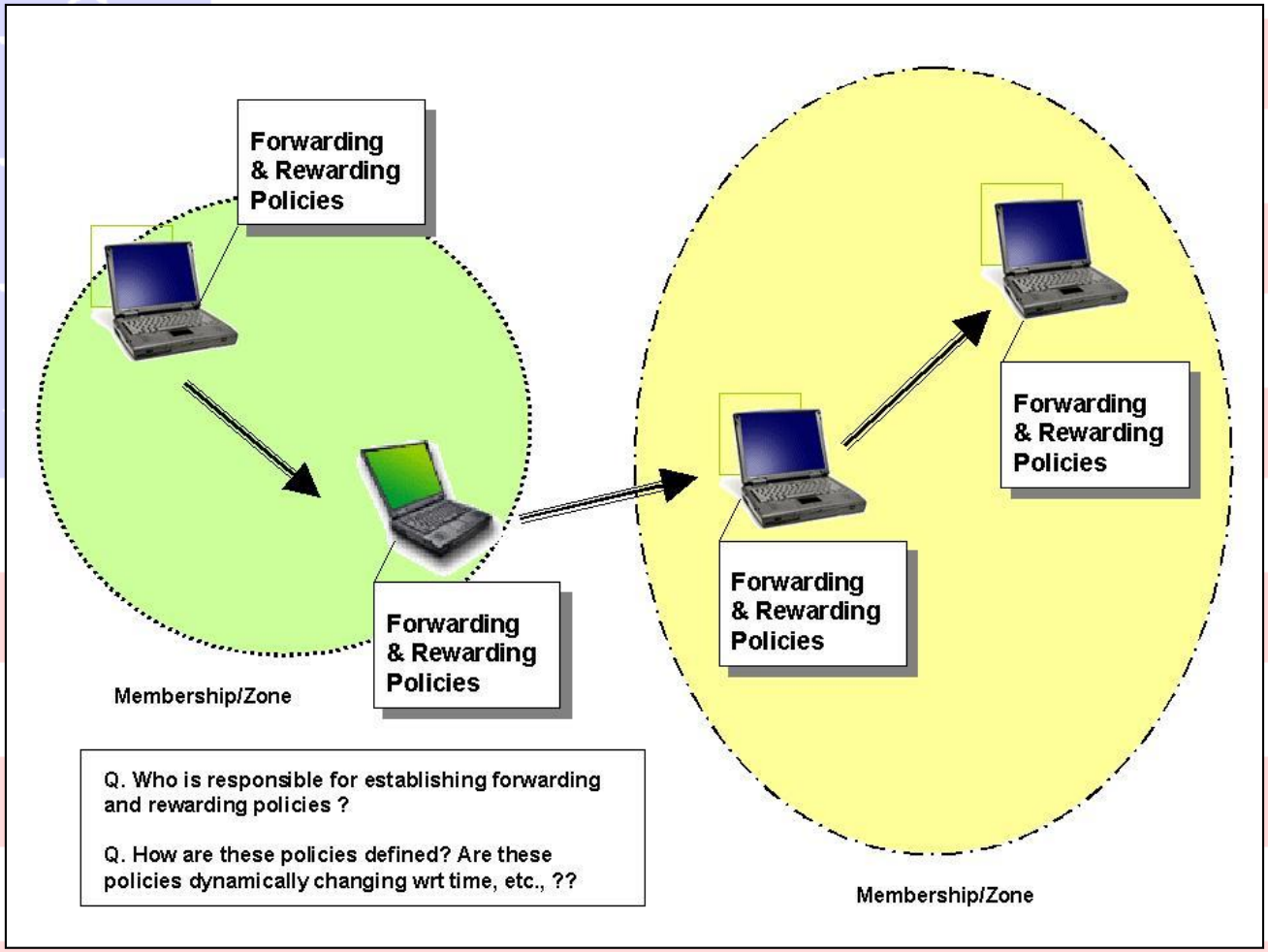
1. **Data forwarded/relayed from one node to another.**
2. **Battery power drain – why do one forward data then???**
3. **Bandwidth consumed with "other" traffic! Why do one allow that??**
4. **Security threats – how do one know that the "data" is not malicious??**



Future: Forwarding Models & Incentives

Further work:

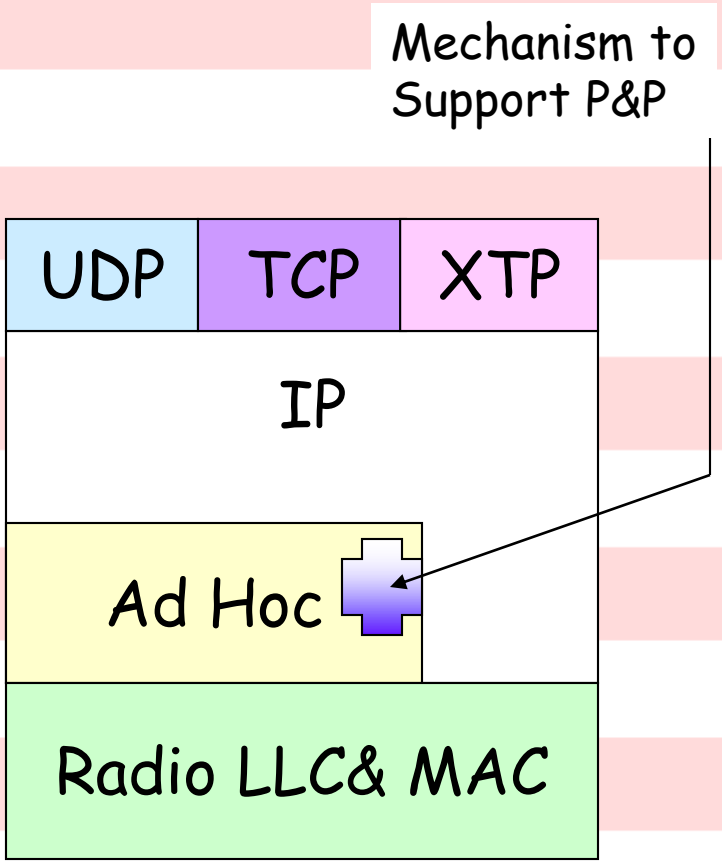
1. Define *forwarding policies*
2. Define *rewarding Policies*
3. Policies made programmable or hard coded?
4. Policies set by user or manufacturer??

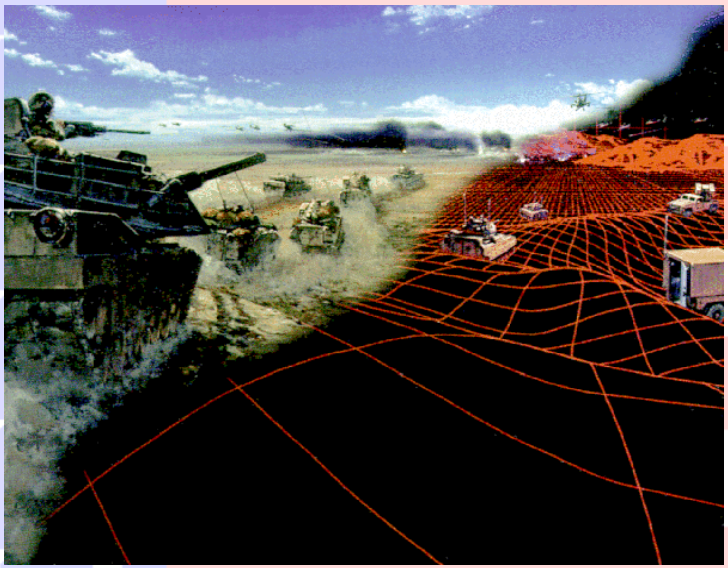


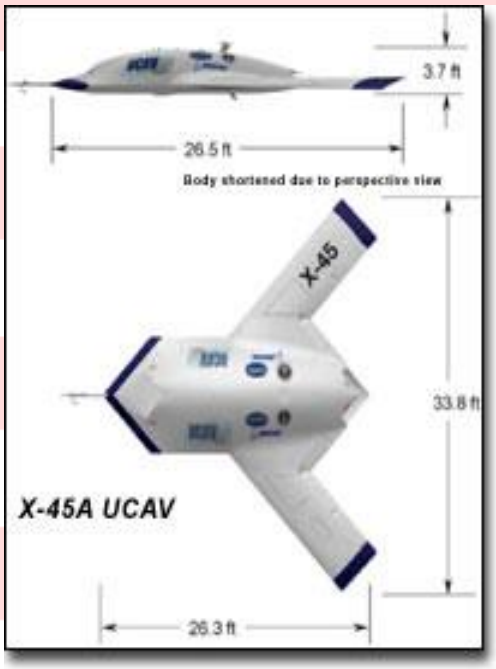
Future: Precedence & Pre-emption

Problem Space:

1. **How can one urgent connection precede another on-going connection?**
2. **How is connection preemption Done?**
3. **Particularly useful for urgent calls, such as 911, 999, or alert messages.**





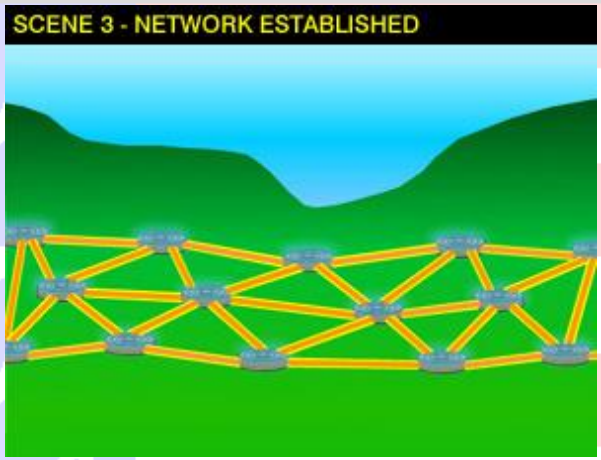


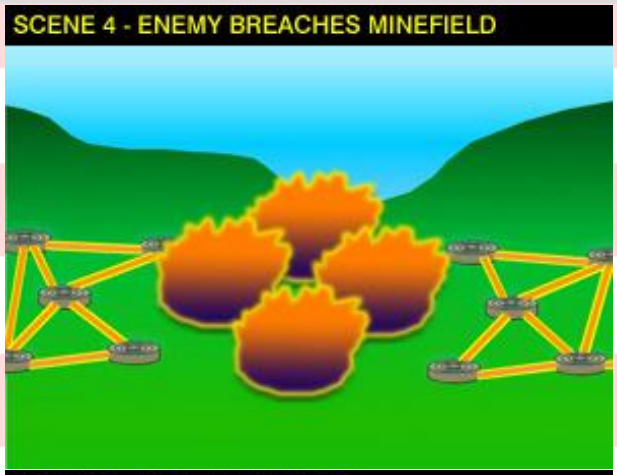
Unmanned Combat Air Vehicle (UCAV) –
Not toys..

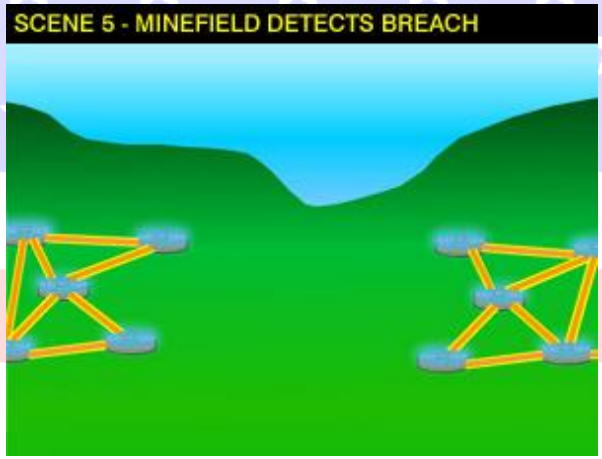
Operational USAF/Boeing UCAV

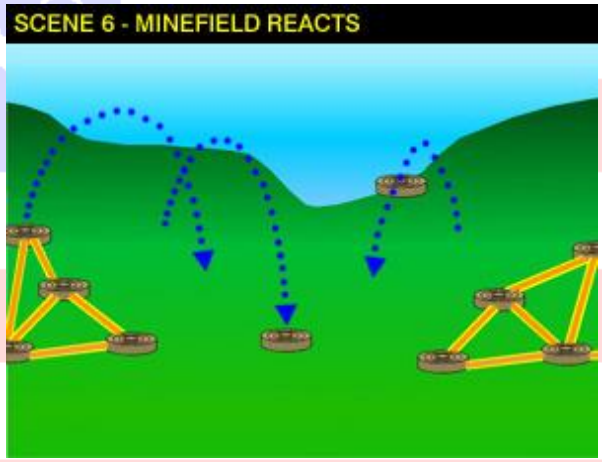
Ad hoc Comms in Higher Altitudes..

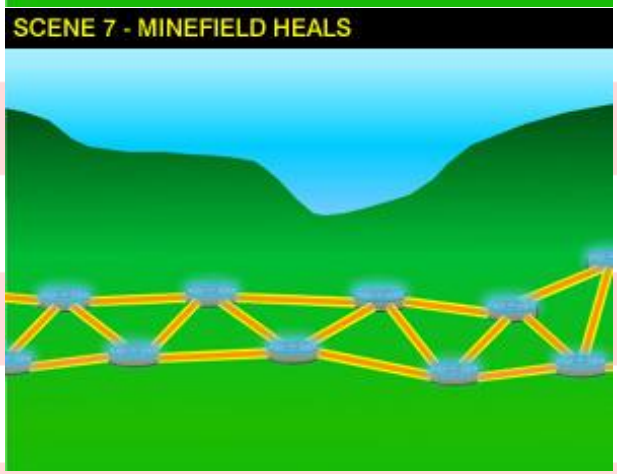
DARPA











DARPA

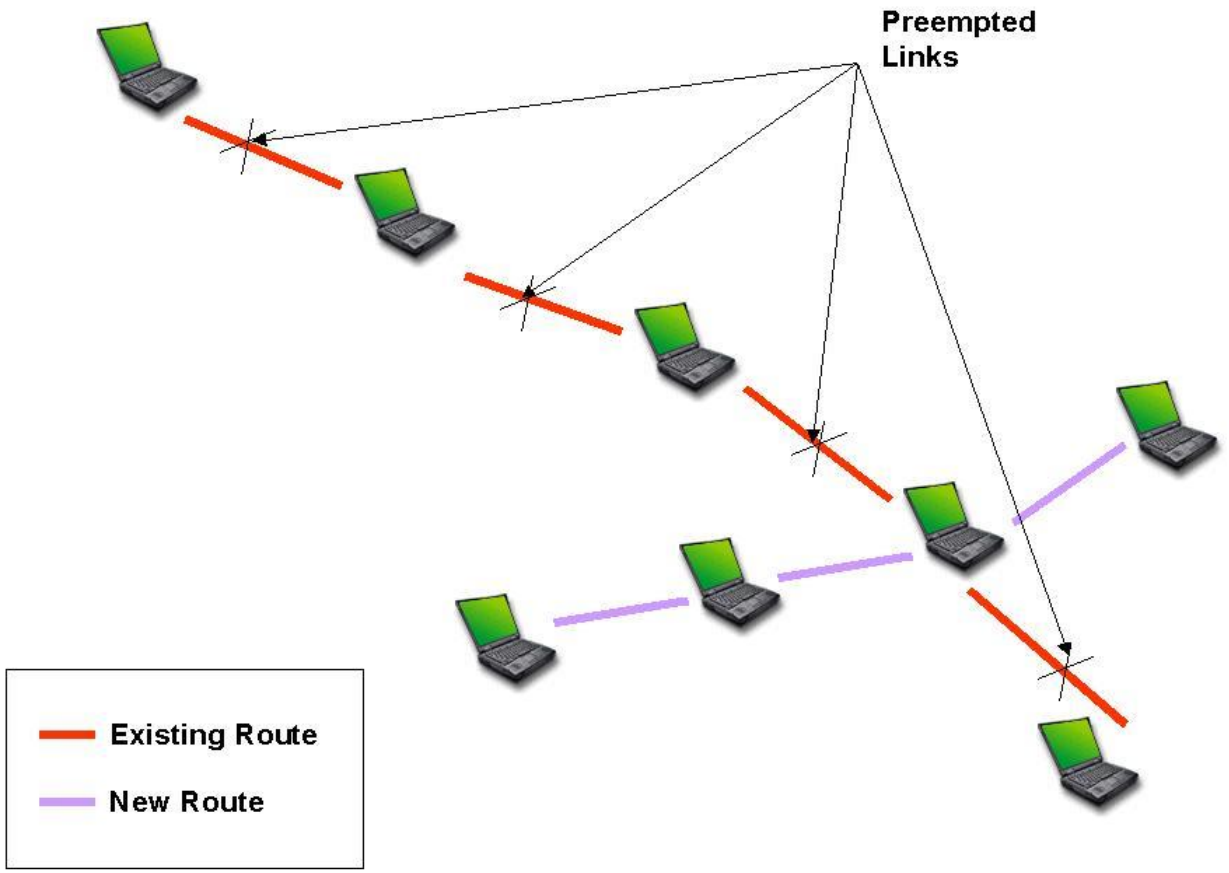
Hopping Mines…

Using ad hoc technology in the battlefield ……

Future: Precedence & Pre-emption

Further work:

1. *User initiated*
2. *Network initiated*
3. Criteria for P&P
4. **Too much P&P mean network communication availability is affected… Hence, need study !**

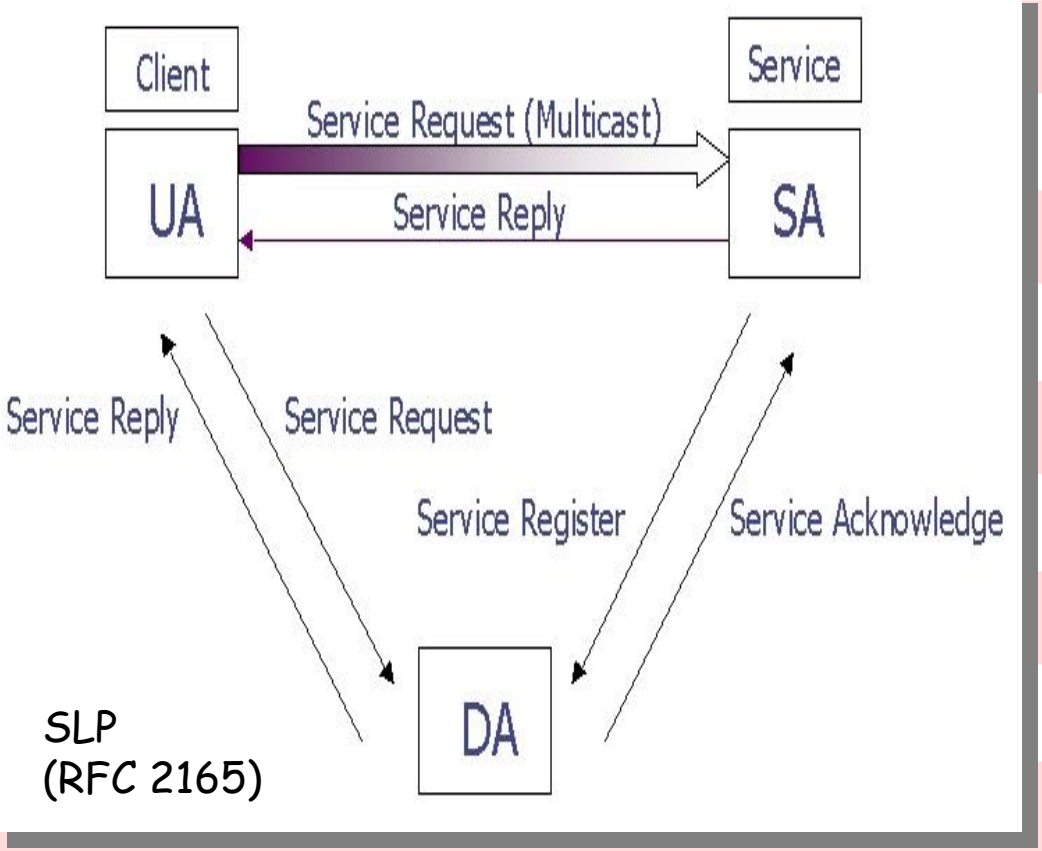


Future: Service Discovery Architectures

Problem Space:

1. **Limitations of current service location protocols**

   + **Presence of mobility of nodes (UA, SA, DA)**
   + **Latency and packet loss issues**
   + **Device heterogeneity Power constraints**

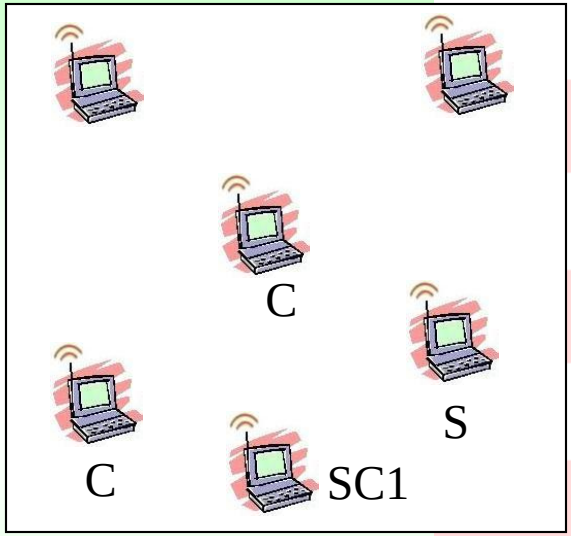


JINI UPnP FORUM The Salutation Consortium Bluetooth

Future: Service Discovery Architectures

Food for thoughts:

1. **Client and server election/ selection procedures….**
2. **How many % servers & clients is optimal or useful?**
3. **How frequent should servers advertise??**
4. **Evaluation of *"service availability", "speed of service access", "overhead of service provisioning", etc.***



Q. How to do service Discovery in ad hoc??

Future:

Implications on Distributed Computing…..

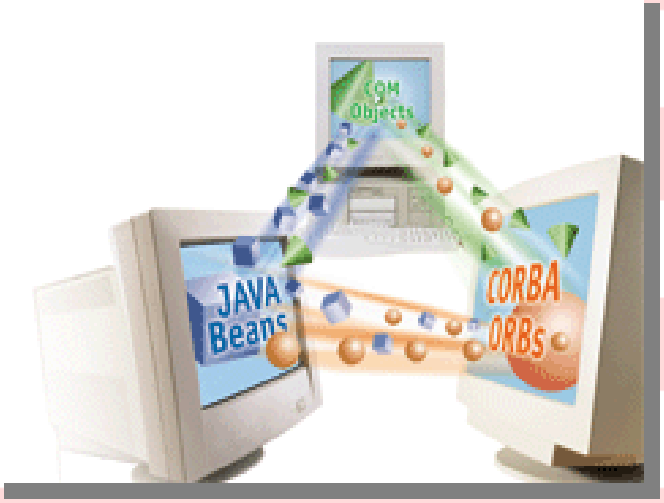
RPC -> Distributed Computing -> Distributed Object Computing (JAVA, CORBA) -> Mobile Agents -> ???

Sounds to me more like sensor data computing/fusion ….

Dr. Bruce Nelson,
inventor of Remote Procedure Call

Wu-Hon Francis Leung, Ph.D.

Was the main inventor on the original patent on Remote Procedure Call in 1978 and developed the first RPC subsystem for the 5ESS® in 1979.



Future 6: Naming & Addressing

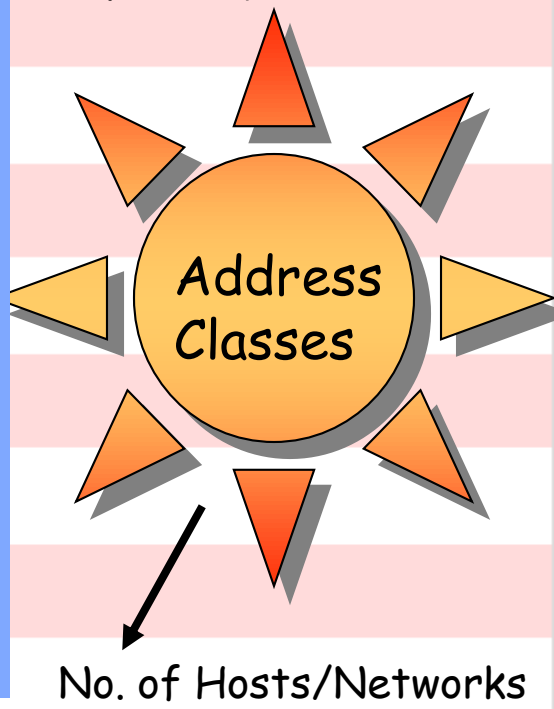
Current Addressing Method

IP Addressing Review

Remember these key points about IP addressing?

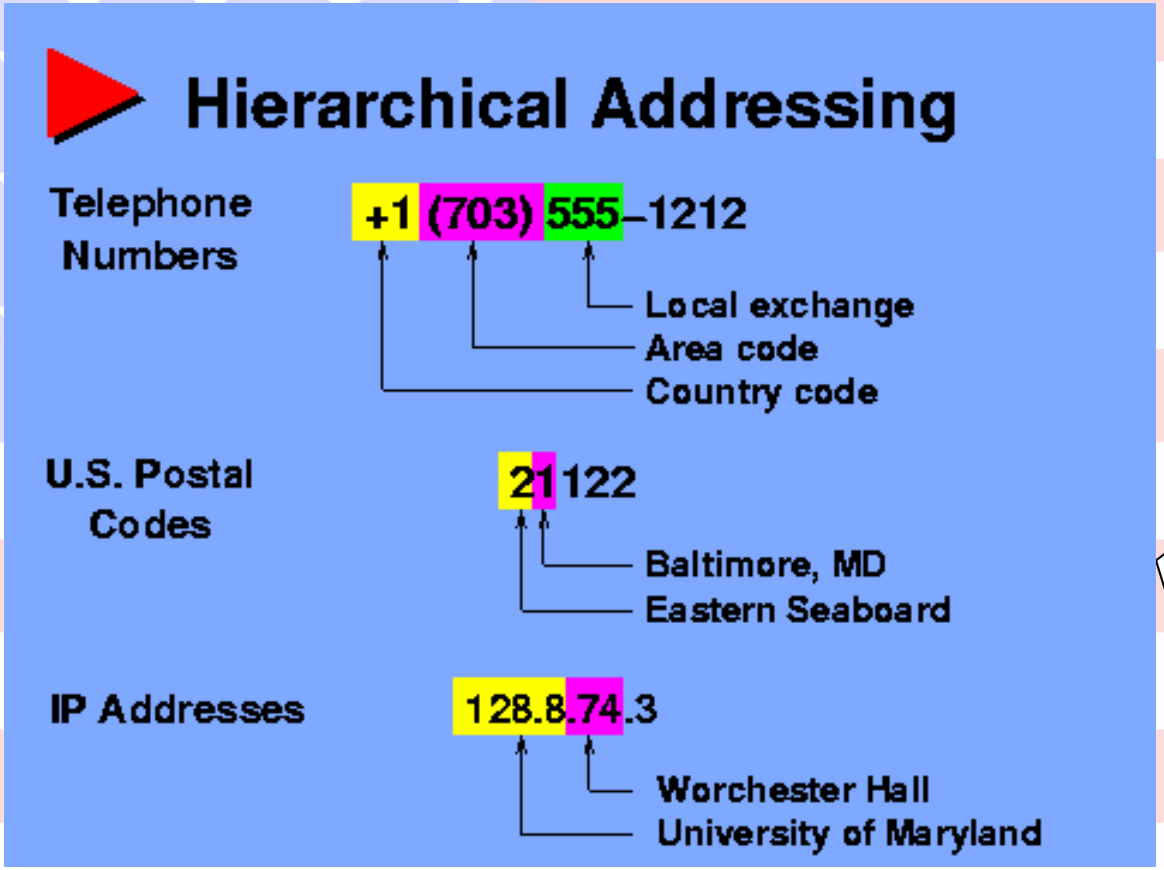
- 32–bit addresses
- "Dotted quad" decimal notation
- Per–interface address assignment
- Address classes – A, B, and C

Subnetting
RFC 590



Future 6: Naming & Addressing

Current Addressing Method



Hierarchy based on regions

How about based on Community??

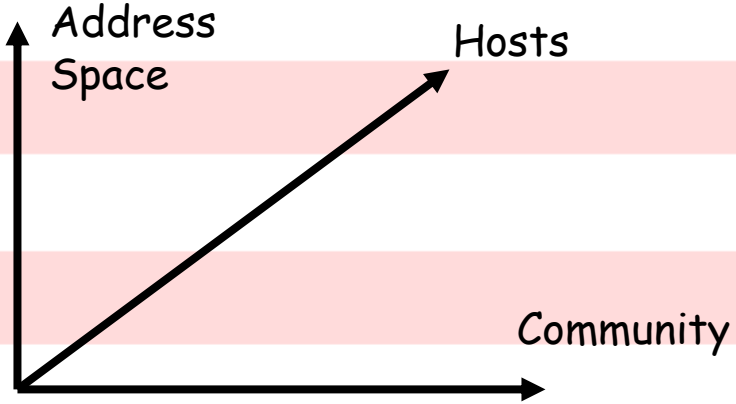
Suitable for ad hoc??

Future 6: Naming & Addressing

Concept of Community

C1 – Fireman Community
C2 – Education Community
C3 – Police Community
C4 – Banker Community
C5 – Singles Community
,,,,,

Q. Can a user can potentially belong to multiple communities??



Q. How do we map communities into IP addresses??

Future 6: Naming & Addressing

Food for thoughts:

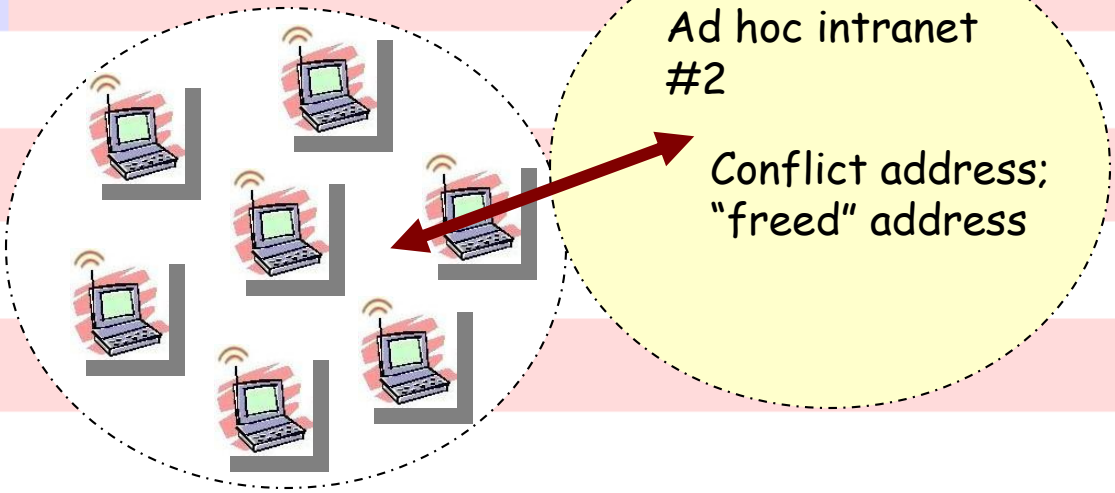
1. **Address Syntax**
2. **Address Initialization**
3. **Address Conflicts**
4. **Address Resolution**
5. **Address Reuse**
6. **Unreachable Host**

199.23.1.0 (IP address?)

MAPPING??

cktoh.anywhere.mobile.com

Where is the DNS???



Future: Ah Hoc Naming & Addressing

Food for thoughts:

1. **Address Syntax** – should address be classified into "classes", "subnetworks" and contains "network" and "host" parts??
2. **Address Initialization** – WHO should initialize each host with appropriate network address?? Recall they need to be unique..
3. **Address Conflicts** – intra ad hoc network migrates into proximity of another. What happens then?? Address conflicts need to be resolved..
4. **Address Resolution** – HOW would a host know about destination node address?
5. **Address Reuse** – migration of an intra-network/nodes away would result in some addresses being "freed" and for "reuse"..

Future: Others,,,,,,

1. Security
2. QoS
3. Multimedia
4. Spectrum
5. ,,,,,

Trusted neighbor -> trusted Friends and friends-of-friends

Secure info -> from packets to Bits

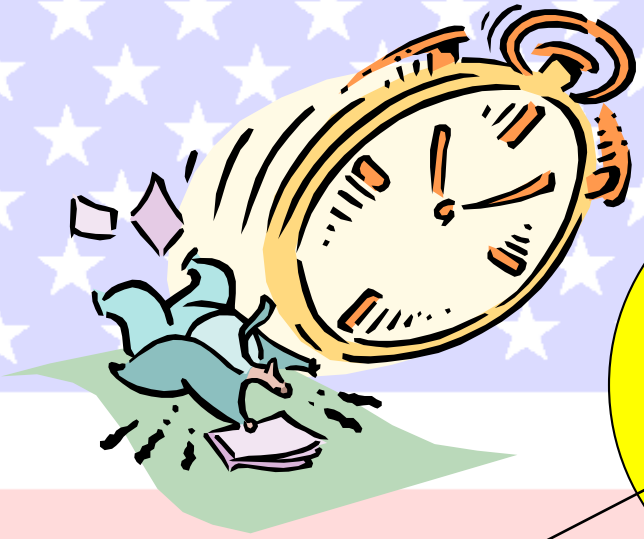
LPI/LPD

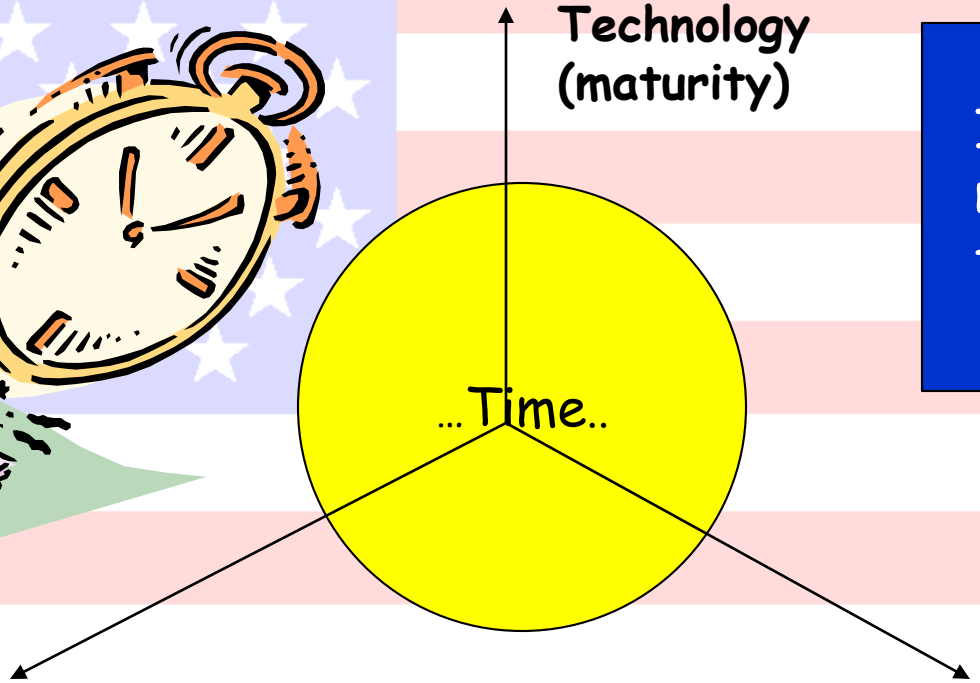
Hard problem… single dimensional ad hoc networks probably insufficient. Need overlays to provide rich connectivity

Audio/video over ad hoc would be very challenging!!

Still in Unlicensed Band??

Future Of Ad Hoc:





I would give it no more than 10 years from now…..

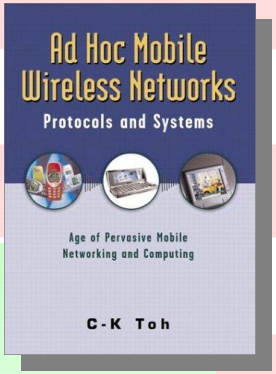
YES for defense….

Conclusion

1. Future is wireless
2. Think beyond – objects can be made physical and alive by implanting them with ad hoc comms technology
3. Past – applications occupied the computing space; useful applications justify the existence of sophisticated computers.
4. Now – computer "rule" the world
5. Future – device / tagged objects are going to rule the world (global pervasive computing/comms)

One more slide left….

Conclusing Remark – from CK's book



Prentice Hall's Best Seller

"Our presence will be felt,
our desires will be met,
our frustrations will be conquered
by
an intelligent, robust,
and user-sensitive
device
network!"

Use the "force"!