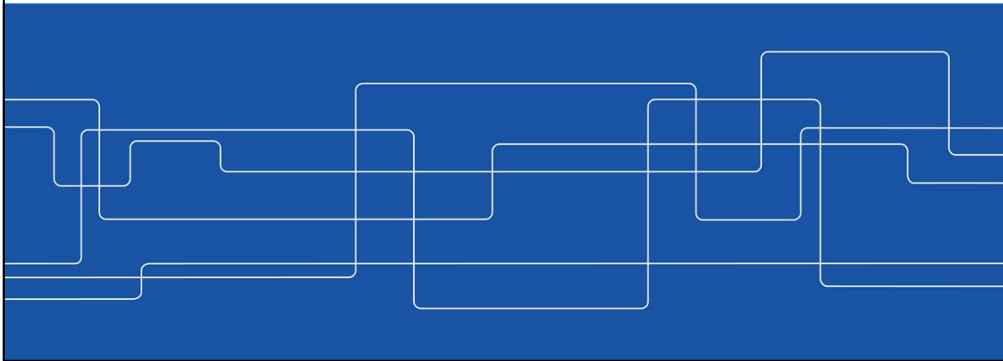




IK1550 & IK1552 Internetworking/Internetteknik

prof. Gerald Q. Maguire Jr. <http://web.ict.kth.se/~maguire>

School of Information and Communication Technology (ICT), KTH Royal Institute of Technology
IK1550/IK1552 Spring 2014, Period 4 2014.04.22 © 2014 G. Q. Maguire Jr. All rights reserved.





Module 11: Mobile IP

Lecture notes of G. Q. Maguire Jr.

For use in conjunction with James F. Kurose and Keith W. Ross, *Computer Networking: A Top-Down Approach*, Fifth Edition, Pearson, 2010.

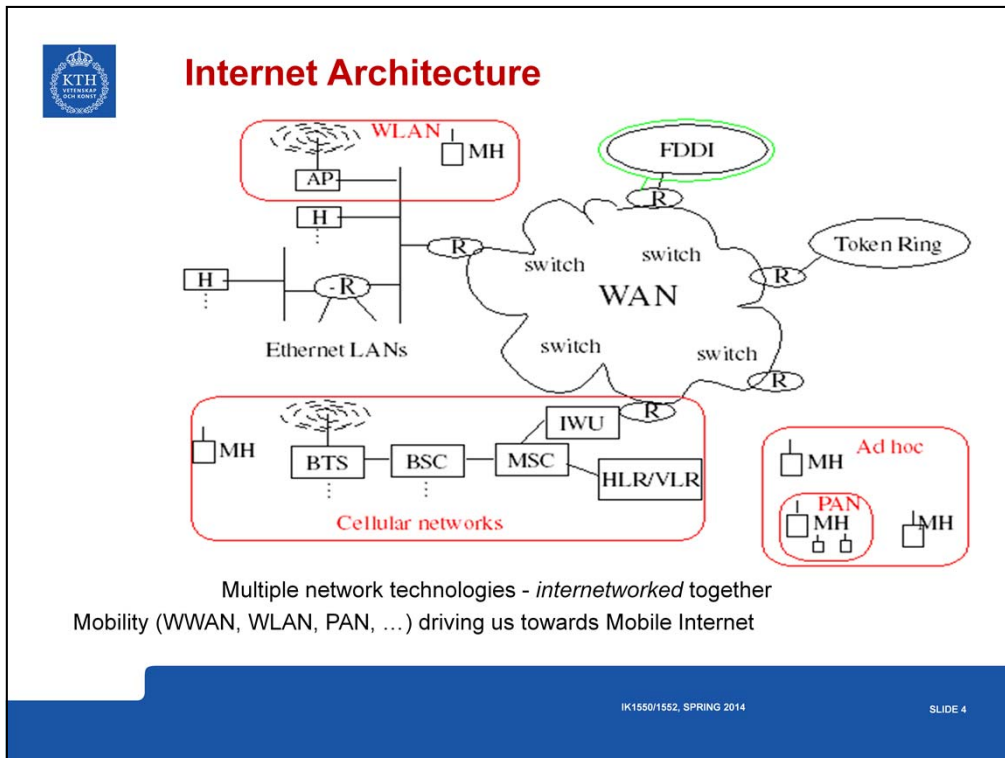
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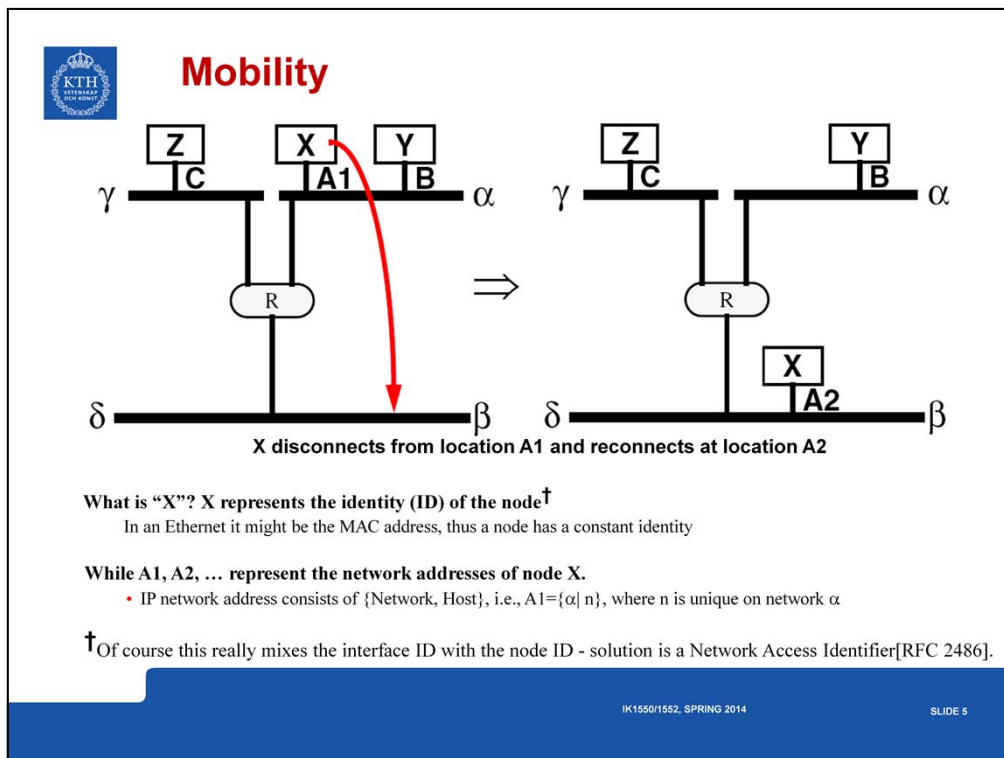
SLIDE 2



Outline


Mobile IP






B. Aboba and M. Beadles, 'The Network Access Identifier', *Internet Request for Comments*, vol. RFC 2486 (Proposed Standard), January 1999, Available at <http://www.rfc-editor.org/rfc/rfc2486.txt>.



B. Aboba, M. Beadles, J. Arkko, and P. Eronen, 'The Network Access Identifier', *Internet Request for Comments*, vol. RFC 4282 (Proposed Standard), December 2005, Available at <http://www.rfc-editor.org/rfc/rfc4282.txt>.



Updating after a move



Host name: **“ccslab1.kth.se”**
Name Resolution: DNS, Host File, ... \leftarrow DNS, Host File, ...
IP address **130.237.15.254** \leftarrow **130.237.216.25**
HW address: **Ethernet MAC address** **08:00:2B:00:EE:0B**



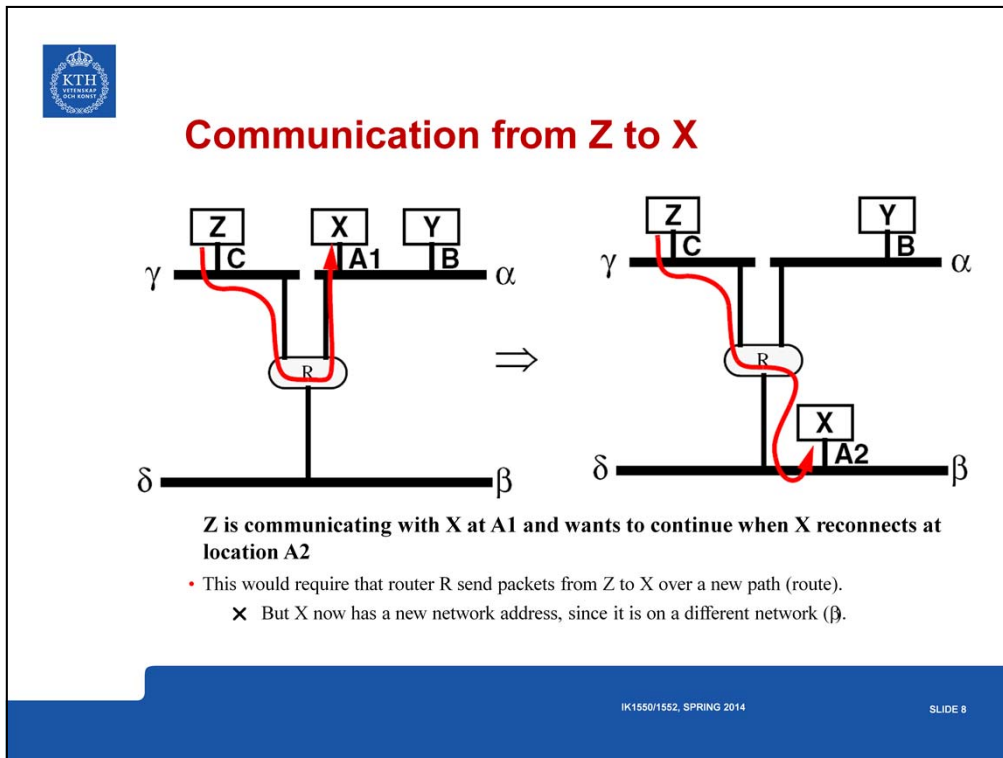
Must update IP address related mappings after a move \Rightarrow administrative nightmare

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Objectives of Mobile IP

- To provide mobility support for the Internet
- To enable node mobility: across changes in IP subnet
- Allow change in location *without* change of IP address
- Communication should be possible (even) while moving (if the interface/link supports it)
- TCP/IP connections should survive movement
- Active TCP and UDP port bindings should be maintained






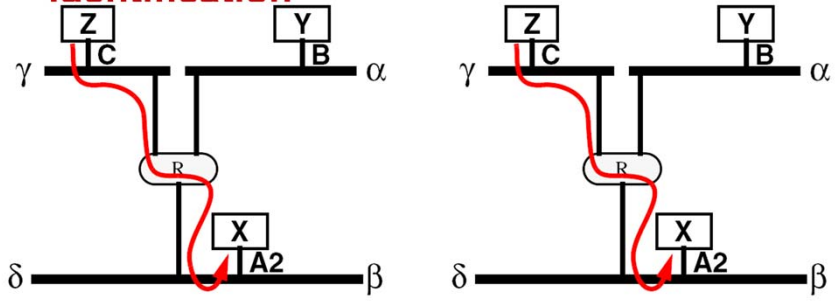
How can Z continue to communication to X?

1. Just use bridging and change the forwarding table in the bridge (since the bridge uses MAC addresses)
 - ✗ But bridging does **not** scale well
2. The application could stop, then restart with the new address for X
 - ✗ This is unpleasant for the user - since they might have to do this very frequently and/or the programs may not tolerate this change - since they have too much state.
3. We could hide this change with a new layer of software
 - a. We could change the socket library
 - ✗ for example: we could do source routing - but, it turns out that this is **not** well supported by existing code in the OS[†] and in router (in addition, many the firewall routers at many sites filter out source routed packets!)
 - ✗ Would require changes in all systems (even the non-mobile systems - since both ends of the communication would have to change)
 - b. We could remap the addresses in the router
 - ✗ This would means doing host specific routing, which does **not** scale well
 - c. We could define a new Mobile-IP address
 - ✓ The implications of this will be described in the following material.

[†] An informal experiment conducted by John Ioannidis as part of this Mobile*IP research (and documented in an appendix of his thesis) indicted that almost all operating systems, of the time, did not correctly support source routing!



Identification



How do we know it is the same X?

When X moves to its new location (A2)

- Why should it get service?
- How do we know it is the same X? (Or even that it is X?)

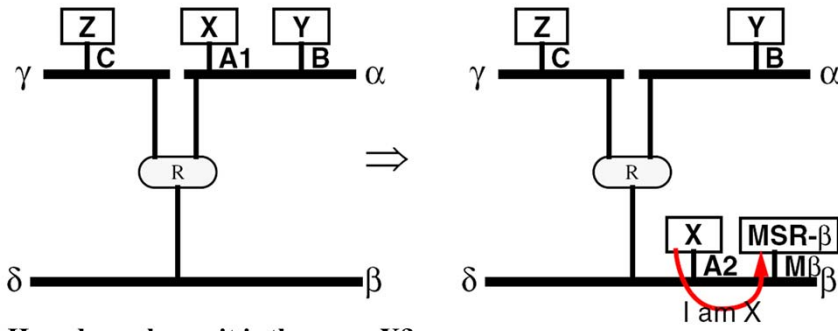
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Establishing Identity

When a node arrives on a network it must identify itself

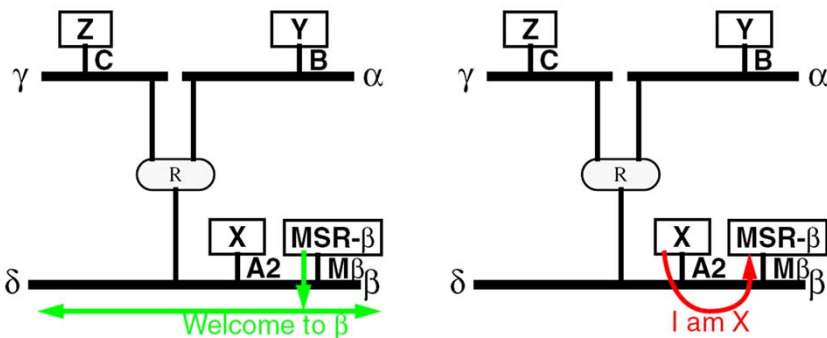
- mechanism: typically via a challenge response protocol
- Who should it identify itself to? **Answer:** The Mobility Support Router (MSR)



How do we know it is the same X?

 **How did it know to send the “I am” message to the MSR?**

When a node arrives on a network it listens for broadcasts from MSRs




“Welcome (Greeting)” messages answered by “I am” messages

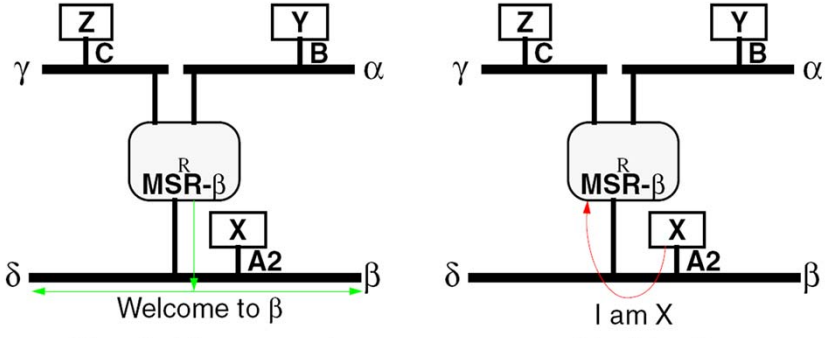
These broadcast “Welcome” messages advertise:

- the presence of an MSR (and its MAC address)
- advertise one or more networks it provides connectivity to

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 **Could the MSR functionality be collocated with the router?**

When a node arrives on a network it listens for broadcasts from MSRs



“Welcome (Greeting)” messages from router answered by “I am” messages

- ✗ Requires updating **all** of the routers on network segments which are going to support mobility to be updated.

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Getting Service

Once it's identity is known, the **policy** question must be asked: **Should X get service?**

The policy question and its answer may involve:

- roaming agreements (generally reciprocal agreements),
- current traffic loads,
- anticipated traffic loads,
- mobile user's priority/class/... ,
-

The question of authentication, authorization, and accounting (AAA) for mobile users is addressed in [Caballero and Malmkvist 2002].


See also IEEE 802.1x Port Based Network Access Control

<http://www.ieee802.org/1/pages/802.1x.html>

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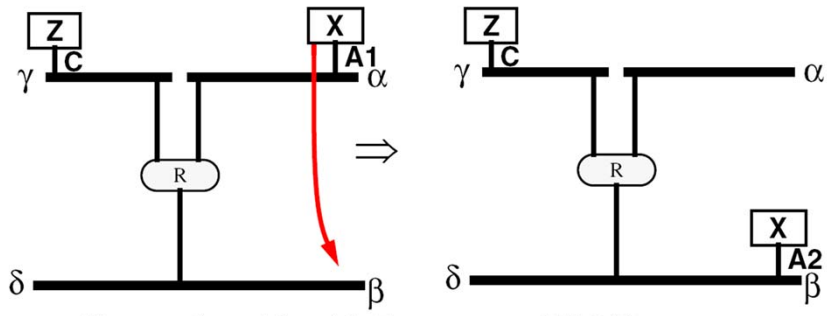
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Juan Caballero Bayerri and Daniel Malmkvist, Experimental Study of a Network Access Server for a public WLAN access network, M.S. Thesis, KTH/IMIT, Jan. 2002



Back to the original problem: Z wants to send a message to X

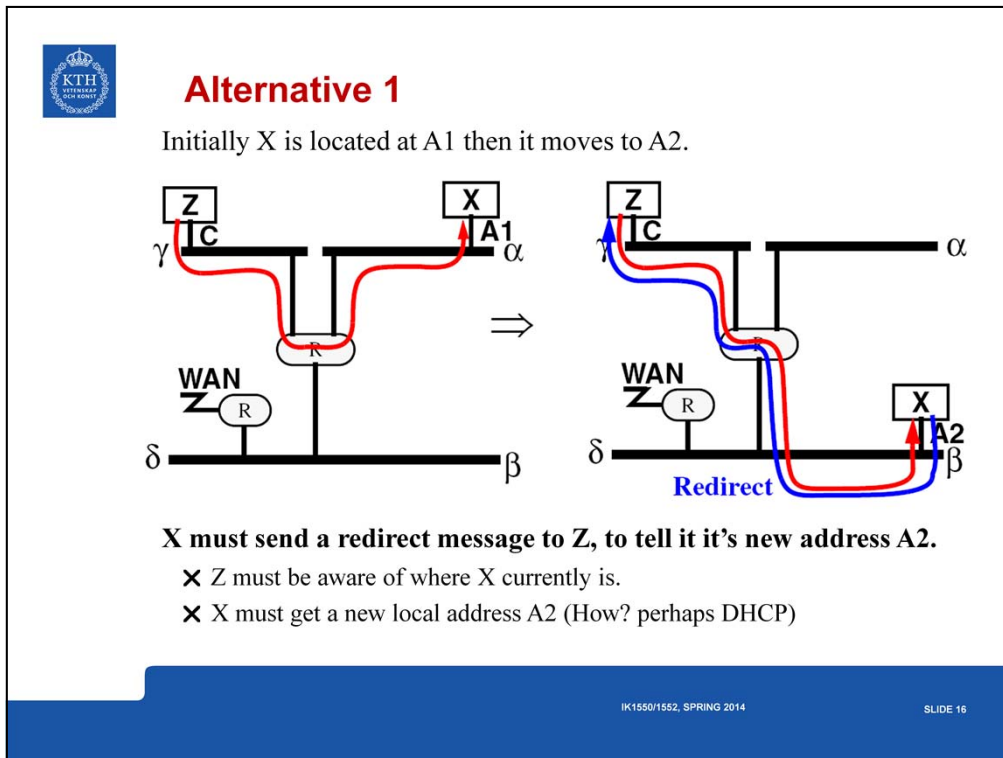
Initially X is located at A1 then it moves to A2.

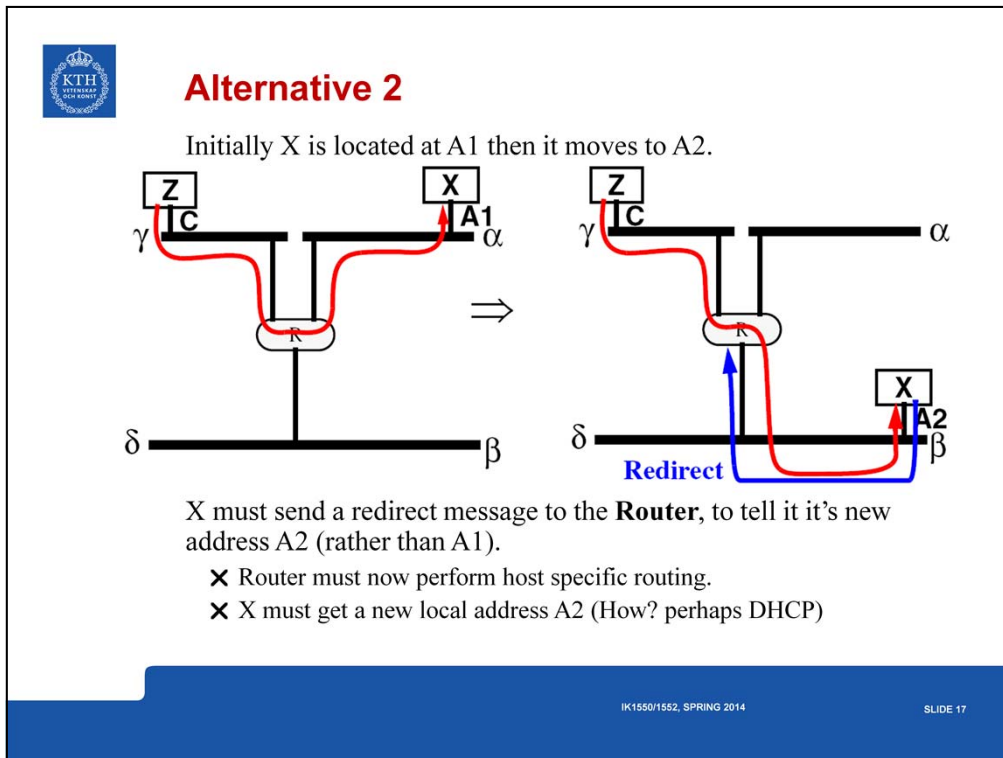


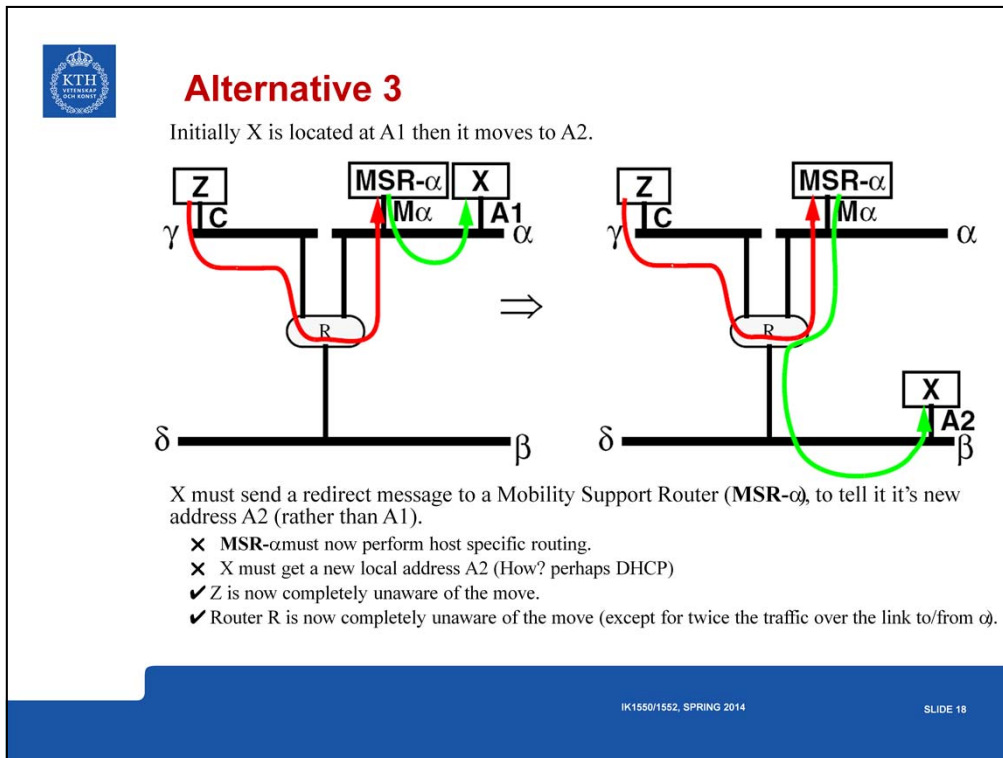
X moves from A1 to A2, Z not aware of Mobility


There are several alternatives.

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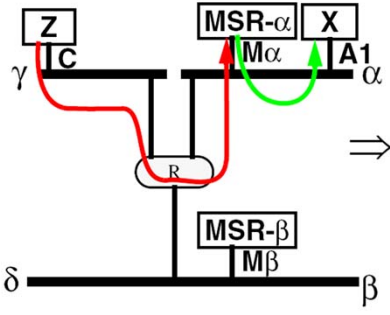
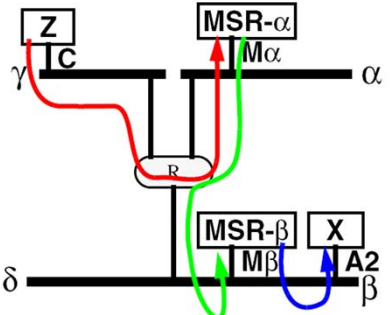






Alternative 4


Initially X is located at A1 then it moves to A2.


⇒


X sends a message to **MSR-β** to get its new address A2 and says its old MSR was **MSR-α**

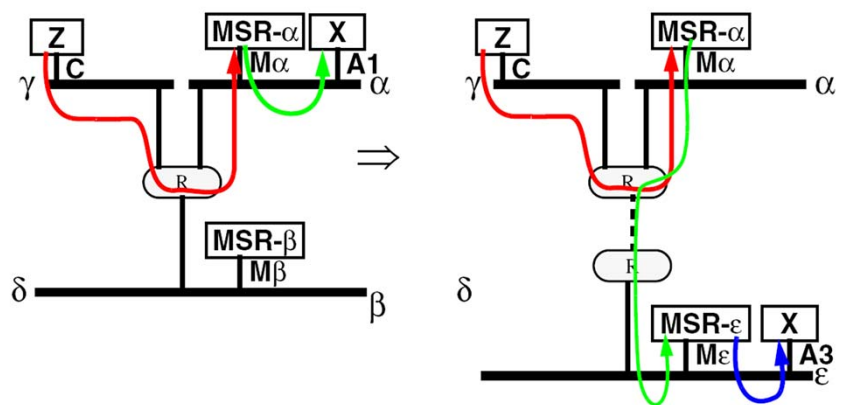
- ✗ **MSR-α** must now perform host specific routing to **MSR-β** (which can provide the local address A2)
- ✓ Z is now completely unaware of the move - it always sends traffic to **MSR-α**
- ✓ If X moves again, Z does not change where it sends traffic to & traffic need not go via **MSR-β** - it will go directly from **MSR-α** to the MSR responsible for the new segment.

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Alternative 4 continued


Initially X is located at A1 then it moves to A2 and then moves to A3.



X sends a message to MSR- ϵ to get its new address A3 and says its old MSR was MSR- α

- ✓ The traffic from MSR- α to MSR- β or MSR- α to MSR- ϵ can be encapsulated, using for example IP in IP (written IP-IP) encapsulation. Thus none of the intervening routers needs know about mobility.

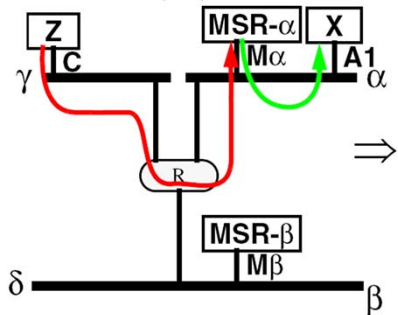
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How does Z know to send things to MSR- α ?

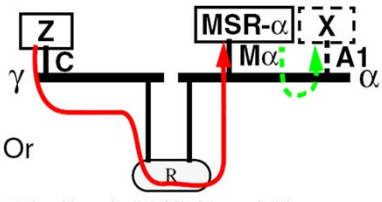
It does **not** know to do this! \Rightarrow Z simply sends the packet to the network address of X.

But what is the (real) network address of X?



\Rightarrow

Or




- X's address is {Mobile-Network,X}
- A1 is a temporary address on network α
- MSR- α routes {Mobile-Network,X} packets to A1 when X is **local** and to another MSR when it is **non-local**

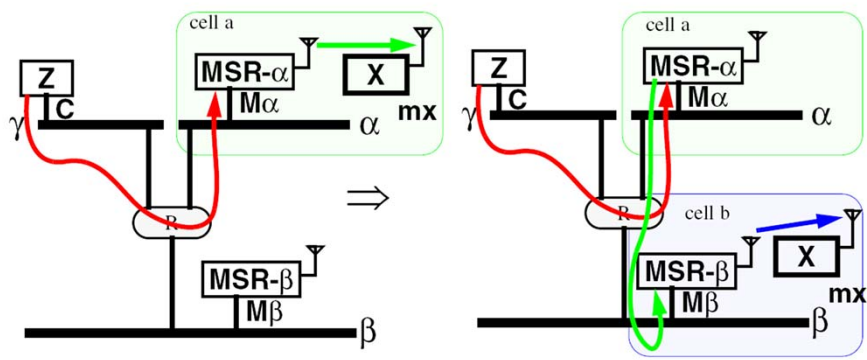
X's address - either on either an actual network or on a virtual network

- ✓ In the first case ("actual" network addresses), either the hosts and routers have to be changed, or MSRs are necessary to intercept and reroute the packets.
- ✓ In the virtual network case, we use the MSRs to implement mobility for nodes on a virtual mobile network.

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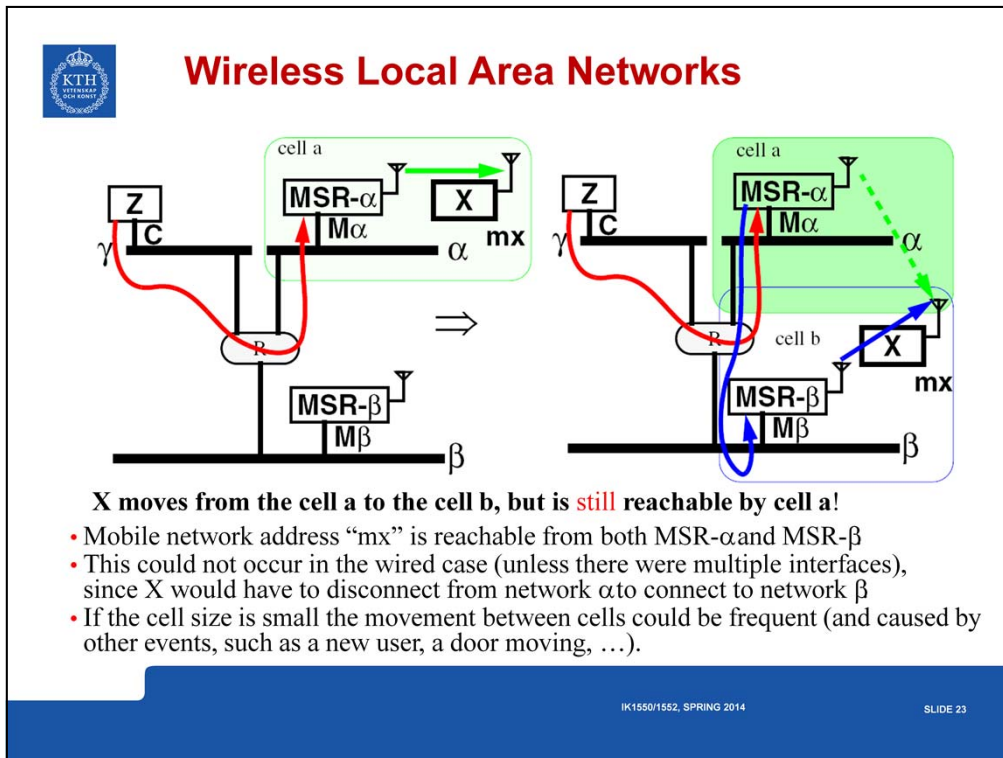
What happens in the case of wireless networks?




X moves from the cell a to the cell b

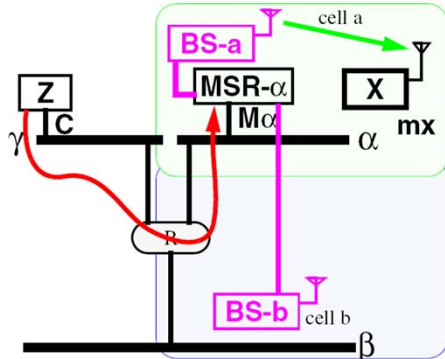
- The wireless cells are implemented by a basestation co-located with the MSR.
- Note that X retains its mobile network address “mx”.

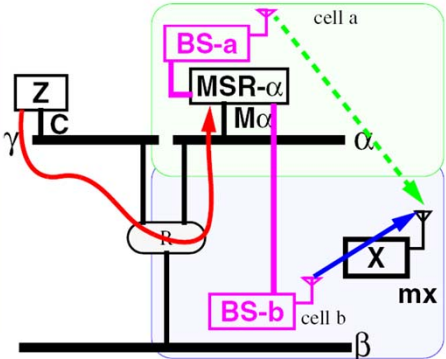
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Wireless WANs




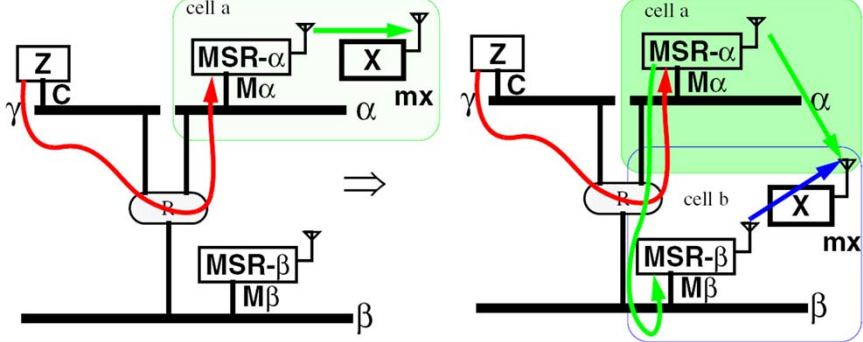


X moves from the cell a to the cell b, but may still be reachable by cell a - but both cells are part of the same network

- Basestation-a, basestation-b, ... are all part of the same network and it is up to this network to select which cell a mobile is in and which basestation will be used to communicate with it.

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 **Simulcasting in Wireless Local Area Networks (WLANs)**



X is moving from the cell a to the cell b

- Mobile network address “mx” is partially reachable from both MSR- α and MSR- β - thus we will send packets via both MSR- α and MSR- β . This insures:
 - ✓ Lower probability of packet loss (important if we must provide low latency and high reliability - such as is needed for voice and some other services)
 - ✗ increases traffic in both cells

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Mobile IP Standardization Effort

- Originally proposed by Columbia University, IBM, etc.
- Internet Engineering Task Force (IETF) Mobile-IP working group (<http://datatracker.ietf.org/wg/mobileip/charter/>)

Mobile-IP standard status:

- RFCs:
 - Mobile-IPv4 (RFC 2002) IP Mobility Support; RFC 2003: IP Encapsulation within IP; RFC 2004, RFC 2005, RFC 2006, etc.
 - Mobile-IPv6: Mobility Support in IPv6 (RFC 3775, 6275), Proxy Mobile IPv6 (RFC 5213), Fast Handovers for Proxy Mobile IPv6 (RFC 5949), ...
- Many Drafts related to v4 & v6:
 - Mobile IP NAI Extension, AAA Registration Keys for MIP, Registration Keys for Route Optimization, Mobile IP Challenge/Response Extensions, CDMA2000 Extension to MIP, Cellular IP, Regional Tunnel Management, Hierarchical MIP Handoffs, etc.

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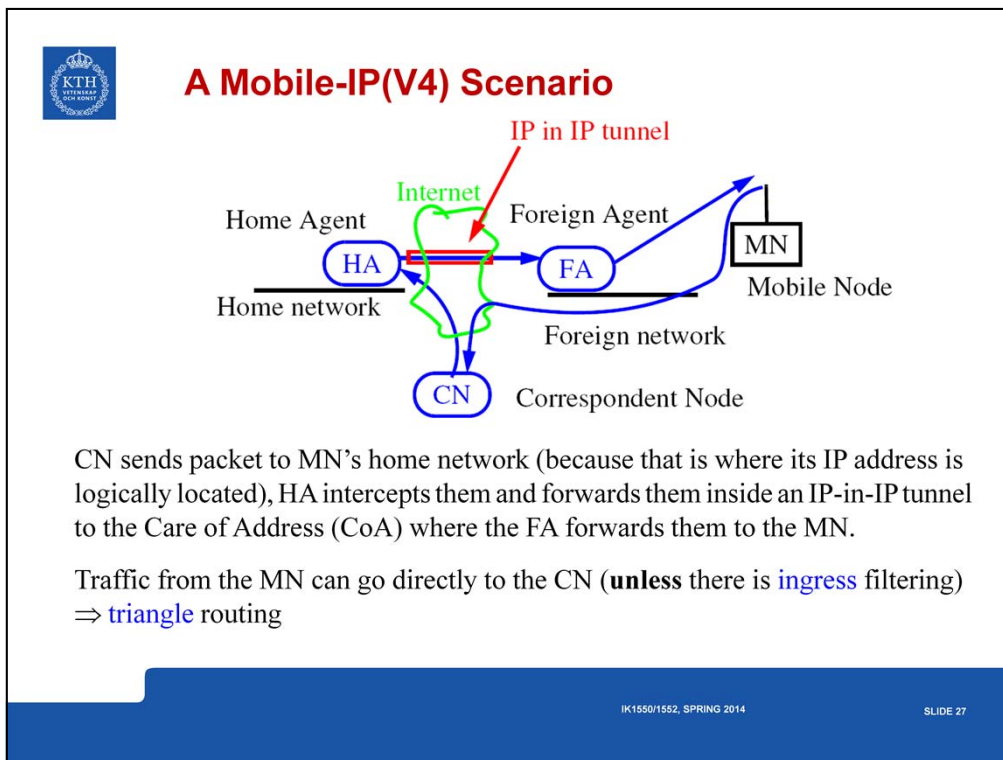
D. Johnson, C. Perkins, and J. Arkko, 'Mobility Support in IPv6', *Internet Request for Comments*, vol. RFC 3775 (Proposed Standard), June 2004, Available at <http://www.rfc-editor.org/rfc/rfc3775.txt>.

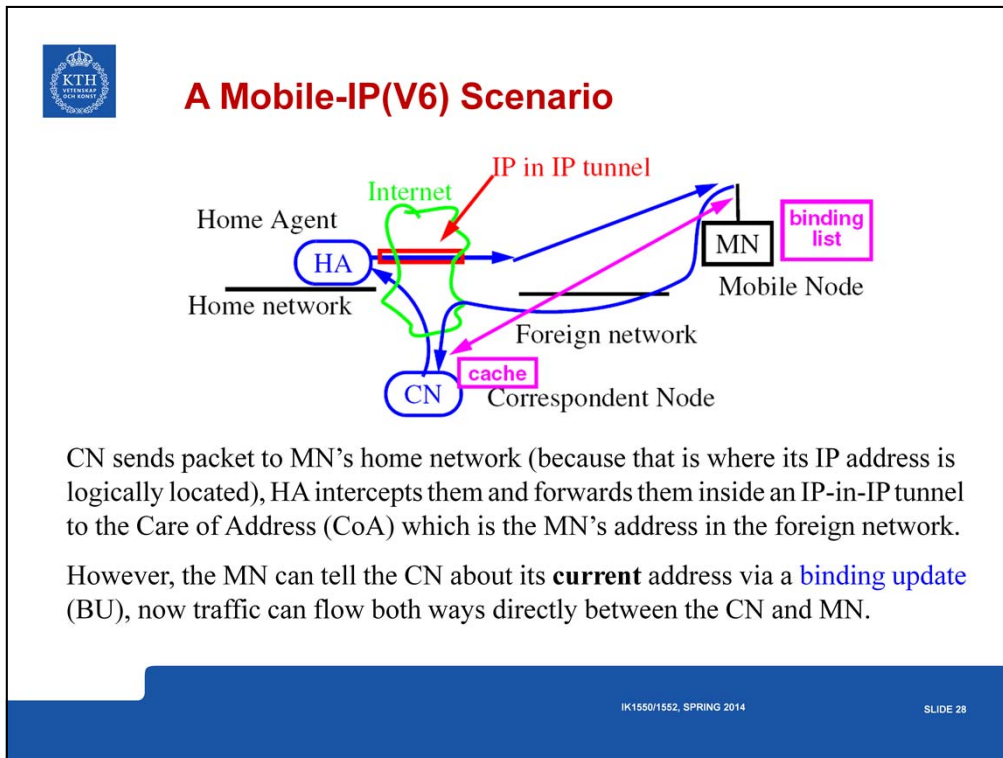
C. Perkins, D. Johnson, and J. Arkko, 'Mobility Support in IPv6', *Internet Request for Comments*, vol. RFC 6275 (Proposed Standard), July 2011, Available at <http://www.rfc-editor.org/rfc/rfc6275.txt>.


S. Gundavelli, K. Leung, V. Devarapalli, K. Chowdhury, and B. Patil, 'Proxy Mobile IPv6', *Internet Request for Comments*, vol. RFC 5213 (Proposed Standard), August 2008, Available at <http://www.rfc-editor.org/rfc/rfc5213.txt>.

H. Yokota, K. Chowdhury, R. Koodli, B. Patil, and F. Xia, 'Fast Handovers for Proxy Mobile IPv6', *Internet Request for Comments*, vol. RFC 5949 (Proposed Standard), September 2010, Available at <http://www.rfc-editor.org/rfc/rfc5949.txt>.

S. Gundavelli, 'Reserved IPv6 Interface Identifier for Proxy Mobile IPv6', *Internet Request for Comments*, vol. RFC 6543 (Proposed Standard), May 2012, Available at <http://www.rfc-editor.org/rfc/rfc6543.txt>.







IP-in-IP Encapsulation

In-in-IP vs. Minimal encapsulation - the major difference is the first puts the whole IP packet inside another, while the later tries to only put a minimal header inside along with the original data portion of the IP packet.

For details see

- IP Encapsulation within IP, RFC 2003
- Minimal Encapsulation within IP, IP RFC 2004

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C. Perkins, 'IP Encapsulation within IP', *Internet Request for Comments*, vol. RFC 2003 (Proposed Standard), October 1996, Available at <http://www.rfc-editor.org/rfc/rfc2003.txt>.

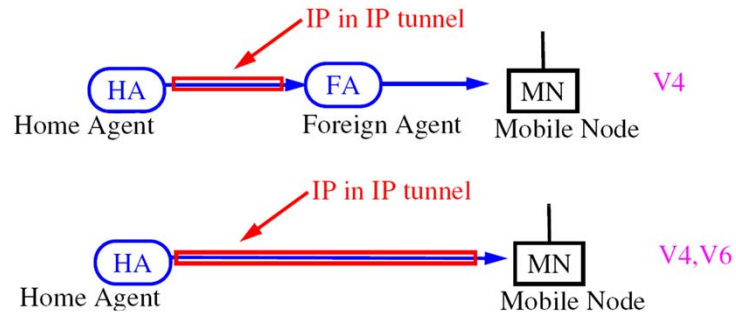
C. Perkins, 'Minimal Encapsulation within IP', *Internet Request for Comments*, vol. RFC 2004 (Proposed Standard), October 1996, Available at <http://www.rfc-editor.org/rfc/rfc2004.txt>.



Tunneling IP Datagrams

Both home agents and foreign agents (v4) must support tunneling datagrams using IP-in-IP encapsulation and decapsulation.

MNs that use a co-located COA must also support decapsulation (v6).





Temporary Address Assignment

Two types of temporary Care-Of-Address:

- **Foreign agent care-of address (V4)**
 - a care-of address provided by a foreign agent through its Agent Advertisement messages.
- **Co-located care-of address (V4, V6)**
 - a care-of address acquired by the mobile node as a local IP address through some external means, e.g. dynamically acquired as a temporary address through dynamic host configuration protocol (DHCP) RFC 1541, or the address may be owned by the MN as a long-term address for its use while visiting this foreign network.

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R. Droms, 'Dynamic Host Configuration Protocol', *Internet Request for Comments*, vol. RFC 1541 (Proposed Standard), October 1993, Available at <http://www.rfc-editor.org/rfc/rfc1541.txt>.

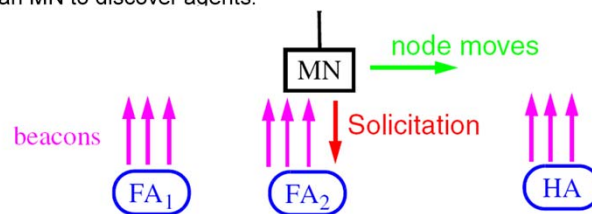


Agent Discovery

Why Agent Discovery?

Methods an MN can use to determine whether it is currently at its home network or a foreign network. By:

- Agent Advertisement
 - periodic transmissions (beacons) sent by a mobility agent (rate limited to max. 1/s).
- Agent Solicitation
 - Send by an MN to discover agents.



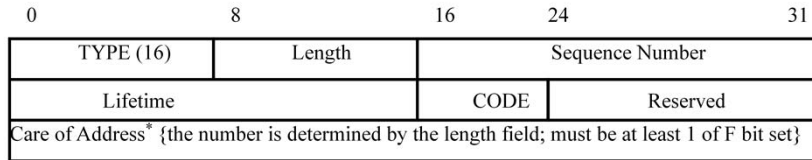
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Agent Advertisement Message Format

Extension of an ICMP router advertisement. Bits of CODE field shown in table.



Bit	Name	Meaning
0	R	Registration with this foreign agent (or another foreign agent on this link) is required; using a co-located care-of address is not permitted.
1	B	Busy. Foreign agent not accepting registrations from additional mobile nodes.
2	H	Agent offers service as a home agent.
3	F	Agent offers service as a foreign agent.
4	M	Agent implements receiving tunneled datagrams that use minimal encapsulation
5	G	Agent implements receiving tunneled datagrams that use GRE encapsulation
6	V	Agent supports Van Jacobson header compression over the link with any registered mobile node.
7		reserved (must be zero)



Registration Message Format

0	8	16	24	31
TYPE (1 or 3)	FLAGS	Lifetime		
Home Address				
Home Agent				
Care of Address* {the number is determined by the length field; must be at least 1 of F bit set}				
Identification				
Extensions				

FLAGS	Bit	Name	Meaning
	0	S	Simultaneous bindings, this is an additional address for the mobile
	1	B	Broadcast datagrams. Home agent to tunnel any broadcast packets it receives to the mobile.
	2	D	Mobile using co-located care-of address and will decapsulation itself
	3	M	Mobile requests home agent to use Minimal encapsulation.
	4	G	Mobile requests home agent to use GRE encapsulation.
	5	V	Mobile node requests that agent use Van Jacobson header compression.
	6-7		reserved (must be zero)

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MN Requirements

An MN must have:

- home address, netmask, and
- mobility security association for each HA.

For each pending registration, MN maintains the following information:

- link-layer address of the FA to which the Registration Request was sent
- IP destination address of the Registration Request
- Care-of address used in the registration
- remaining lifetime of the registration



FA Requirements (v4)

- Each FA must be configured with a **care-of-address**.
- Must maintain a **visitor list** with following information:
 - Link-layer source address of the mobile node
 - IP Source Address (the MN's Home Address)
 - UDP Source Port
 - Home Agent address
 - Requested registration Lifetime
 - Identification field

This visitor list acts much like a [Visitor Location Register \(VLR\)](#) in a cellular system.



HA Requirements

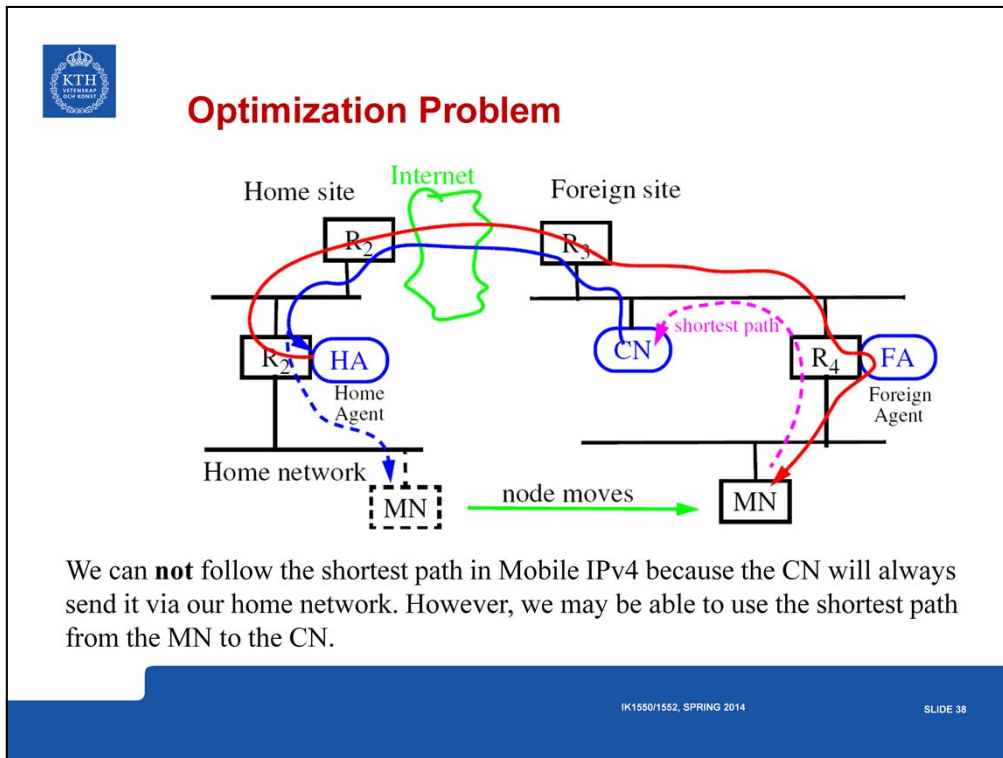
Each HA must have:


- the home address and mobility security association of each authorized MN that it is serving as a home agent.

Must create or modify its **mobility binding list** entry containing:

- Mobile node's CoA (or CoAs in the case of simultaneous bindings)
- Identification field from the Registration Request
- Remaining Lifetime of the registration

The mobility binding list acts much like a [Home Location Register \(HLR\)](#) in a cellular system.





Problems of Mobile IP (RFC 2002)

<ul style="list-style-type: none"> • Only provides basic “macro mobility” support • Not developed for cellular systems • No interface defined between cellular systems (e.g. between Mobile-IP/HLR/VLR) • No handover support 	} ⇒ Cellular Micro Mobility
<ul style="list-style-type: none"> • Weak in security • No key distribution mechanism 	Security
<ul style="list-style-type: none"> • Route optimization problems 	⇒ Optimization
<ul style="list-style-type: none"> • No QoS, real-time support, (DiffServ, RSVP) 	⇒ QoS and Real-time
<ul style="list-style-type: none"> • ... 	

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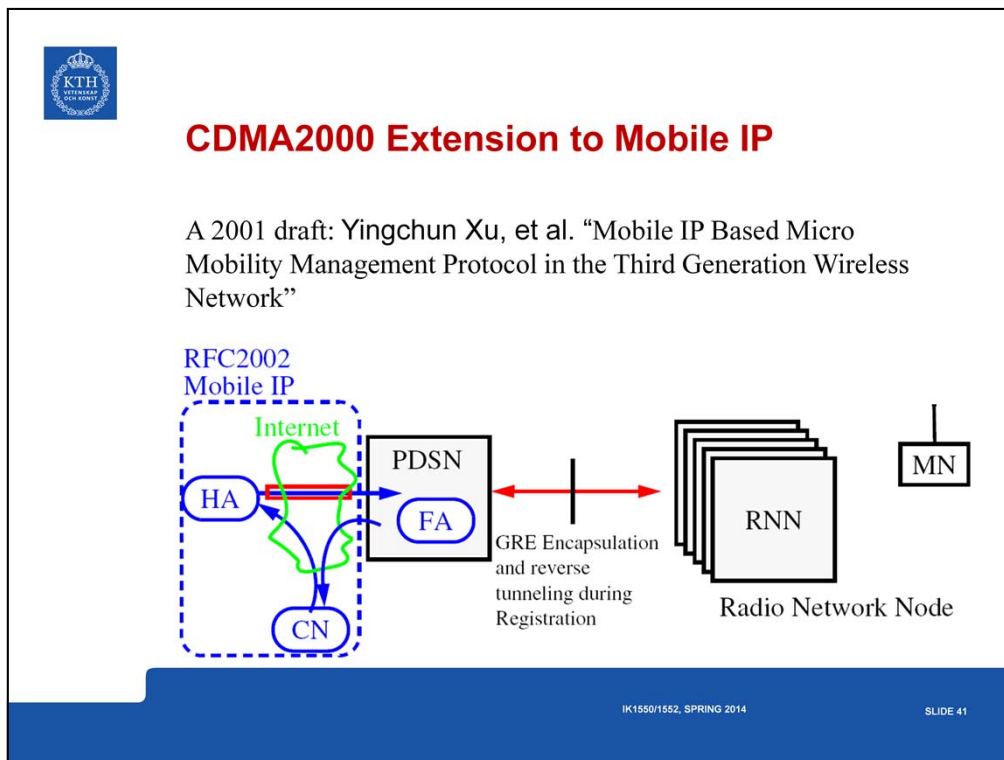
C. Perkins, ‘IP Mobility Support’, *Internet Request for Comments*, vol. RFC 2002 (Proposed Standard), October 1996, Available at <http://www.rfc-editor.org/rfc/rfc2002.txt>.

C. Perkins, ‘IP Mobility Support for IPv4’, *Internet Request for Comments*, vol. RFC 3220 (Proposed Standard), January 2002, Available at <http://www.rfc-editor.org/rfc/rfc3220.txt>.



Mobile IP Problems and Development

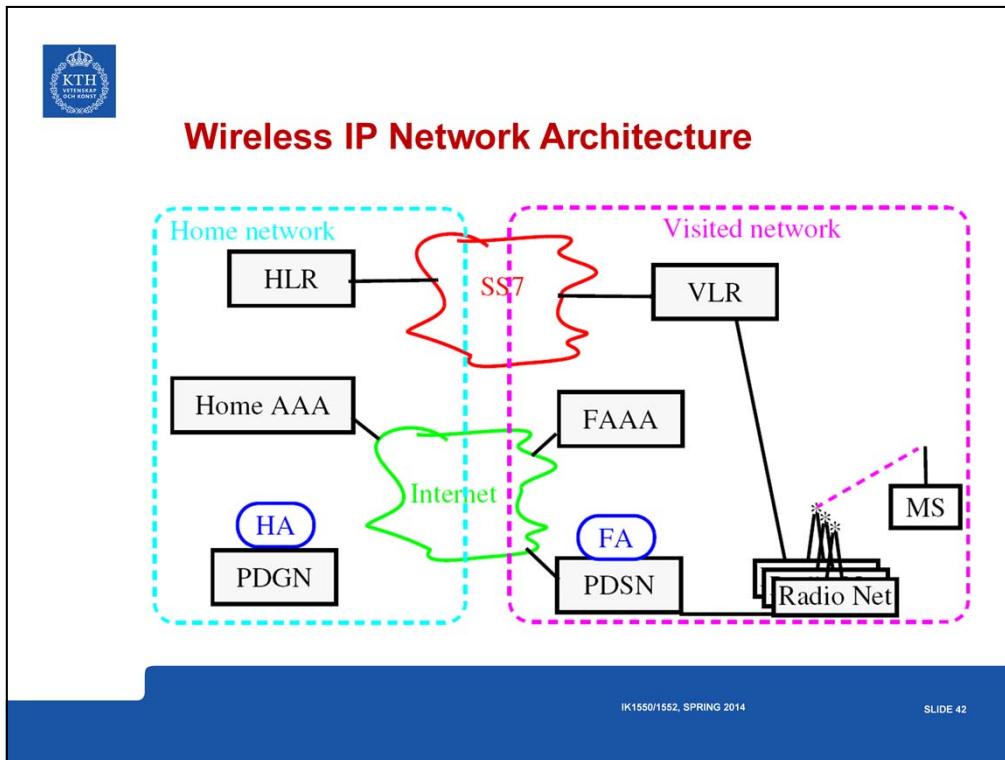
- Cellular Micro Mobility:
 - CDMA2000 Extension to MIP
 - Cellular IP
 - Regional Tunnel Management
 - Hierarchical MIPv6 Handoffs
 - MIP based Micro Mobility Management
- Security:
 - Mobile IP NAI Extension
 - AAA Registration Keys for MIP
 - Registration Keys for Route
 - Mobile IP Challenge/Response Extensions
- Route Optimization:
 - Route optimization for MIPv4, v6
- Real-time QoS:
 - No solution yet

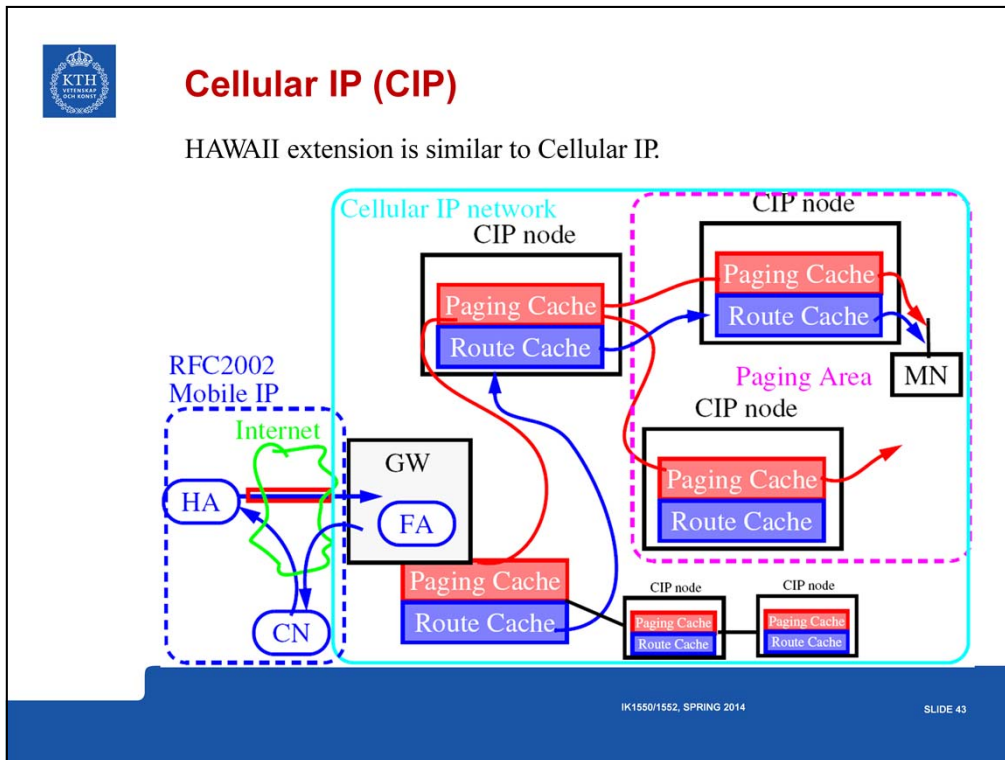


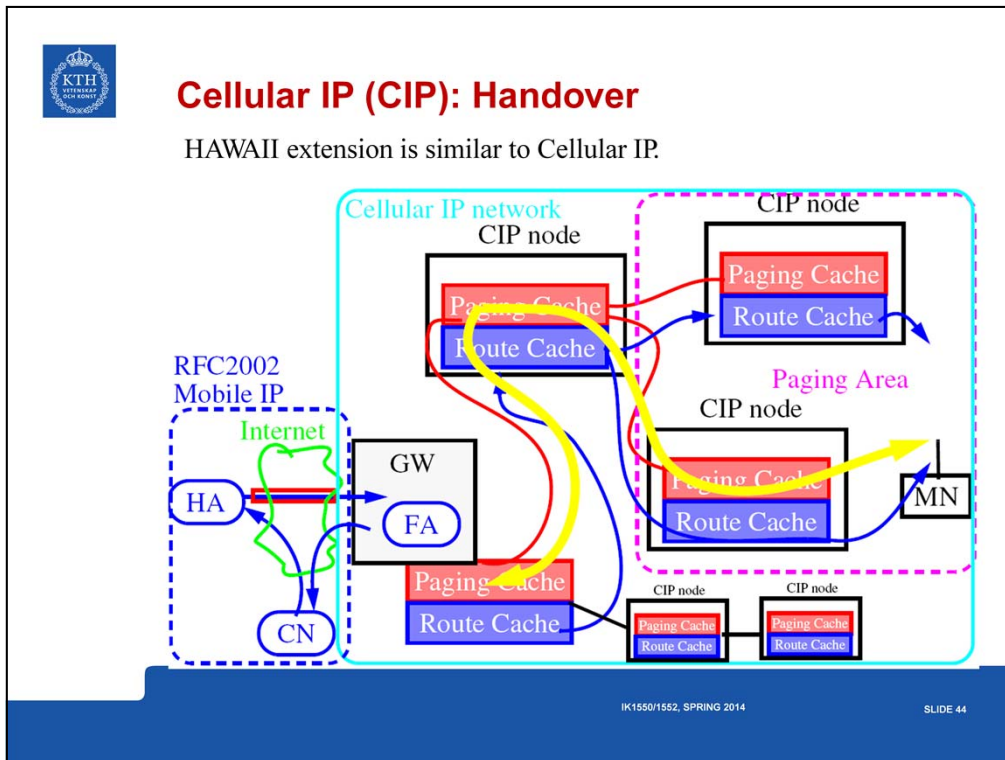
Yingchun Xu, Rajesh Bhalla, Ed Campbell, Karl Freter, Eileen McGrath Hadwen, Gopal Dommety, Kirit Joshi, Parviz Yegani, Takeo Matsumura, Atsushi Teshima, Lee Dong Hyun, Naoto Itoh, Kimihiro Ohki, Byung-Keun Lim, Peter J. McCann, Thomas Towle, Jay Jayapalan, Peter W. Wenzel, Carey B. Becker, James Jiang, Shota Shikano, Woojune Kim, Yong Chang, Bill Semper, Jun Mo Koo, Mark A. Lipford, Frederic Leroudier, and Jim Gately,
 "Mobile IP Based Micro Mobility Management Protocol in The Third Generation Wireless Network",

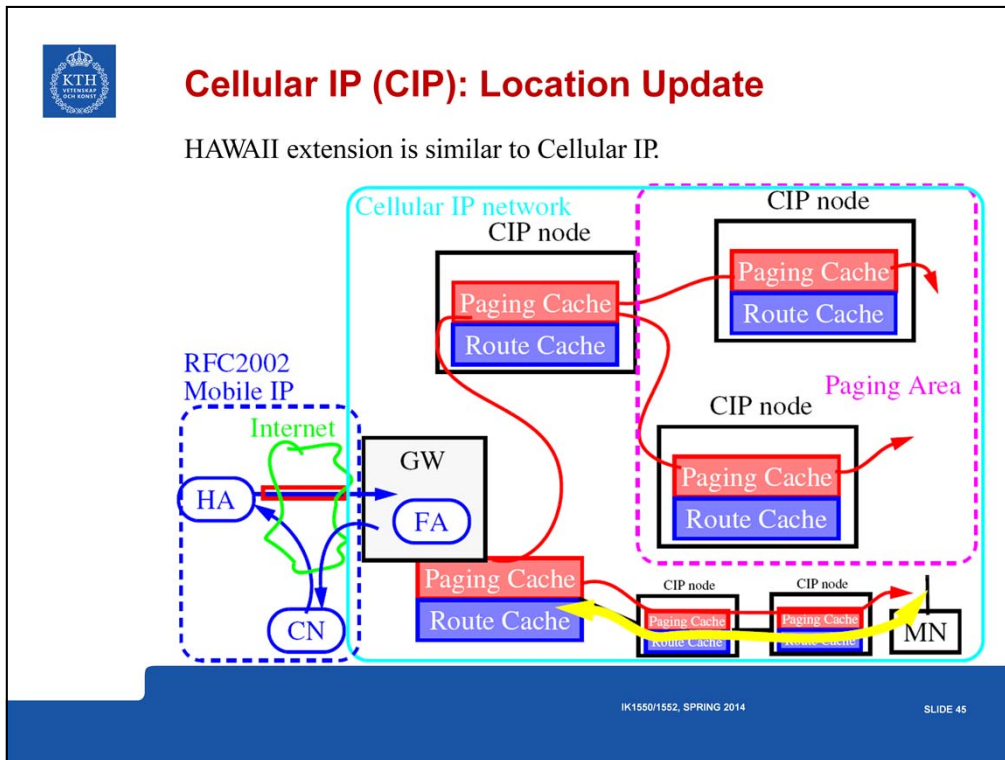
Internet Draft, May, 2001, Expires Nov. 2001, draft-ietf-mobileip-3gwireless-ext-06.txt

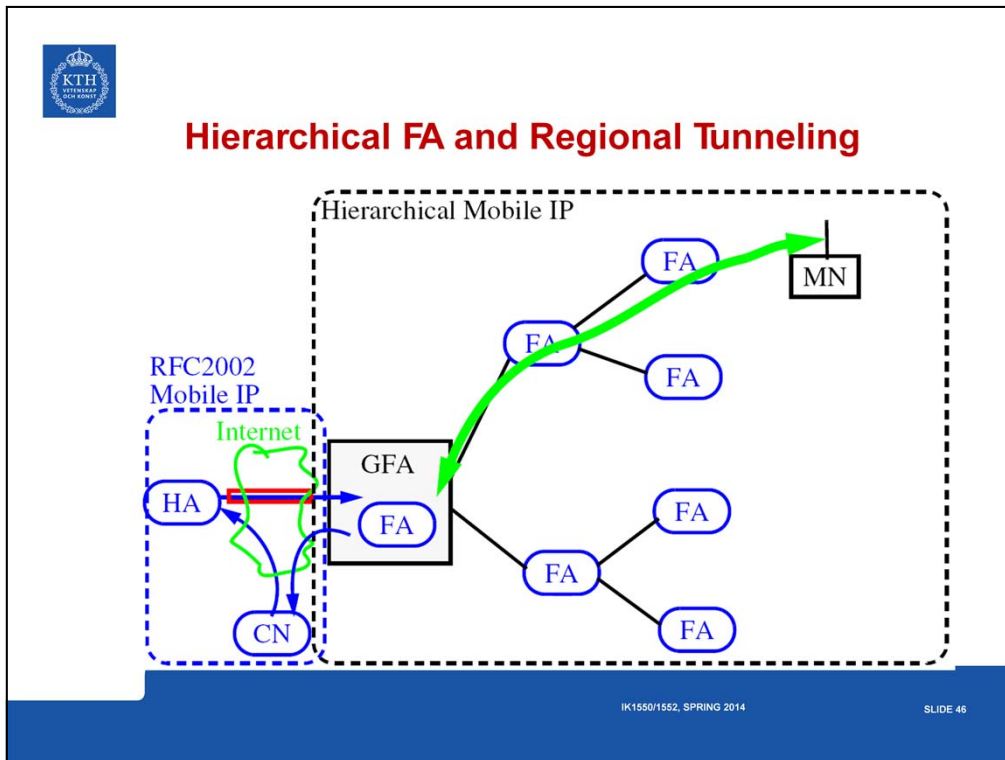
<http://www.ietf.org/proceedings/52/I-D/draft-ietf-mobileip-3gwireless-ext-06.txt>





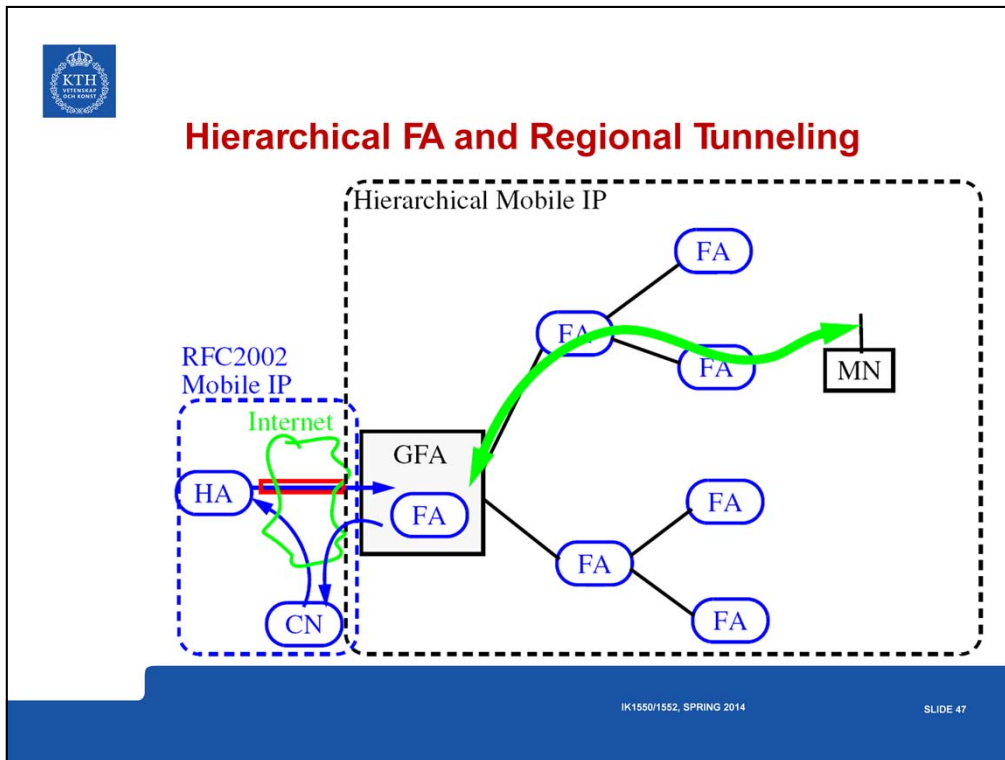






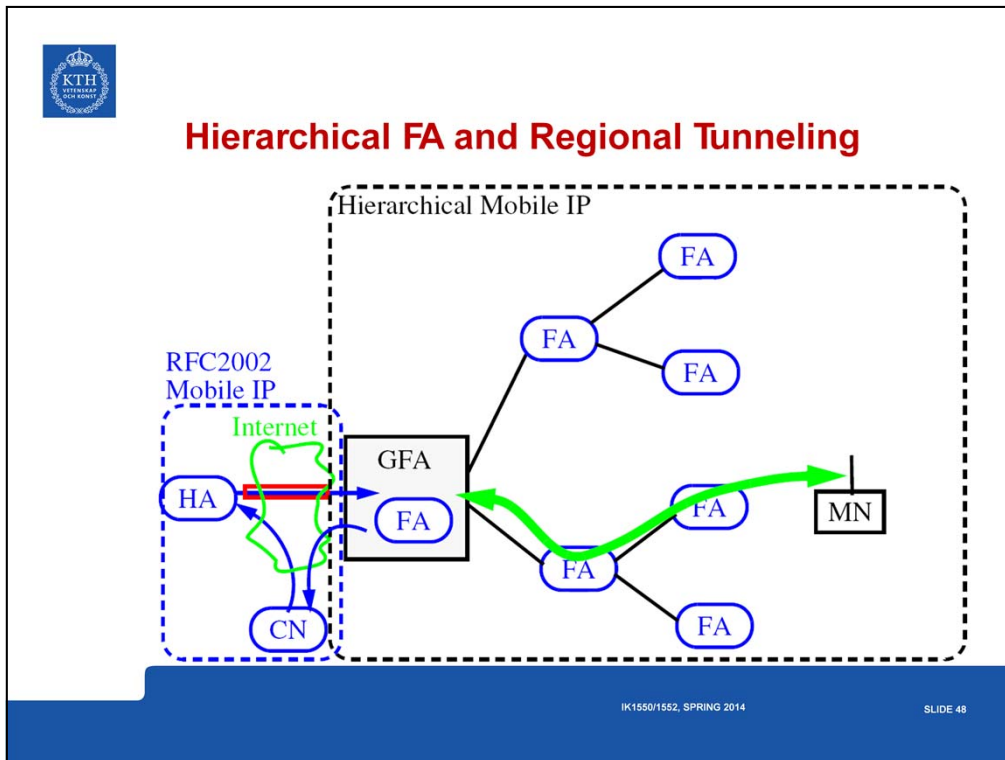
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Why not simply use Dynamic DNS (DDNS)?

Problems of Dynamic DNS Mobility

- Only support inter-session mobility.
- TCP has to be disconnected when changing net.
- No inter-networking handover.
- Performance limitation problems.
- Security, Intranet firewall, etc.

	Mobile IP	Dynamic DNS
TCP survive the movement	Yes	No
Intra-session mobility	Yes	No
Handover Support	(Working on)	No
Performance Limitation	No	Yes

Thus DDNS does not really provide mobility, just connecting at different places.



Further reading

- Charles E. Perkins, *Mobile IP: Design Principles and Practices*, Addison-Wesley, 1998, ISBN 0-201-63469-4.
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- I. F. Akyildiz, Jiang Xie, and S. Mohanty, 'A survey of mobility management in next-generation all-IP-based wireless systems', *IEEE Wireless Communications*, vol. 11, no. 4, pp. 16–28, August 2004, DOI:10.1109/MWC.2004.1325888.
- A. T. Campbell and J. Gomez-Castellanos, 'IP micro-mobility protocols', *ACM SIGMOBILE Mobile Computing and Communications Review*, vol. 4, no. 4, pp. 45–53, October 2000, DOI:10.1145/380516.380537.



Summary

This module has discussed Mobile IP.



¿Questions?

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