KUNGL TEKNISKA HÖGSKOLAN
Institutionen för teleinformatik
CCSlab

2G1305 Internetworking/Internetteknik
Winter 2002, Period 3

Module 7: Future and Summary

Lecture notes of G. Q. Maguire Jr.

Lecture 7: Outline

- Mobile IP
- IP SANs (Storage Area Networks): iSCSI, …
- A glimpse into the future.

Network Address Translation

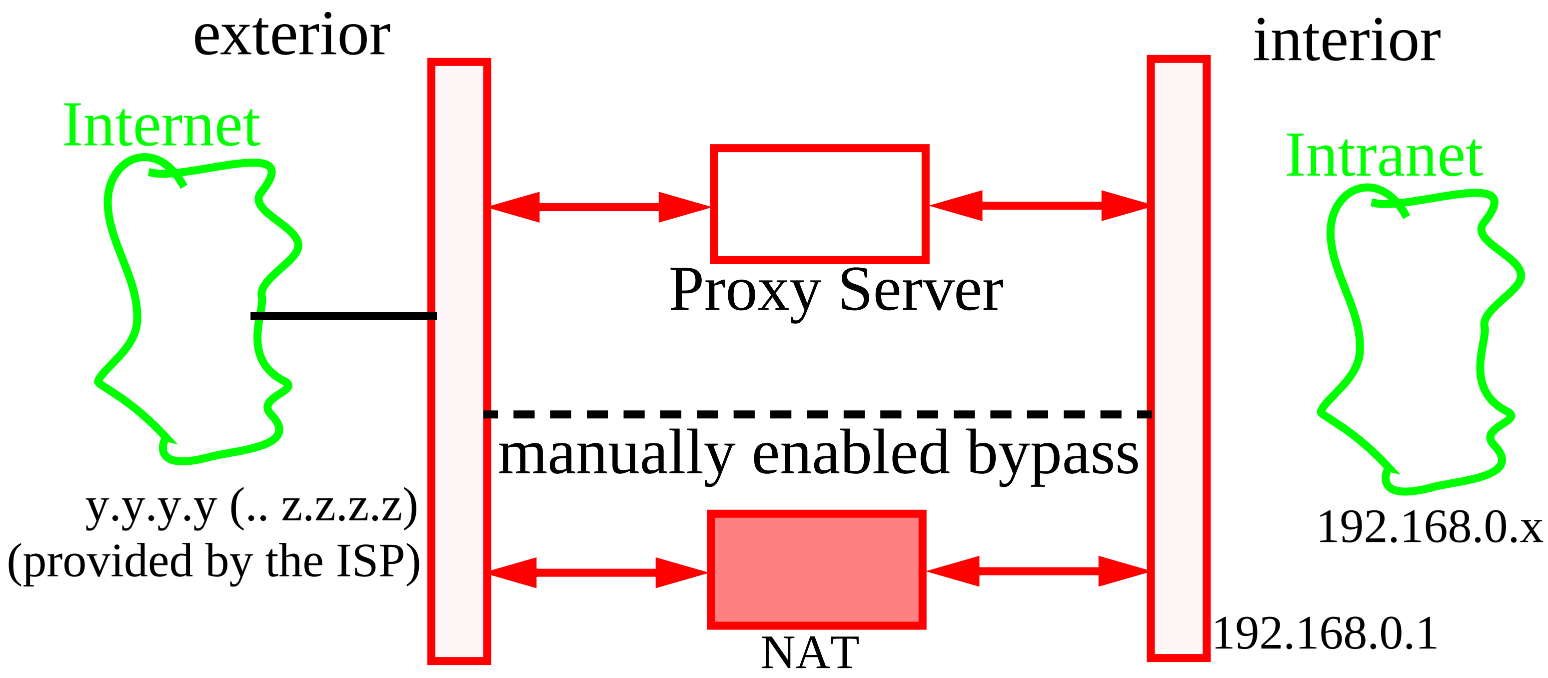


Figure 65: Firewall with NAT

NAT maps IP addresses on the inside to one or more addresses on the outside and vice versa. See RFC1631: The IP Network Address Translator (NAT), RFC263: IP Network Address Translator (NAT) Terminology and Considerations, and RFC2766: Network Address Translation -Protocol Translation (NAT-PT).

Advantages:

- ✔ save IPv4 addresses
- ✔ hides internal node structure from outside nodes
- ✔ the intranet does not have to be renumbered when you connect to another ISP

Disadvantage

- ✘ Unfortunately this breaks many services because they use an IP address inside the their data.

Emerging Network Architecture

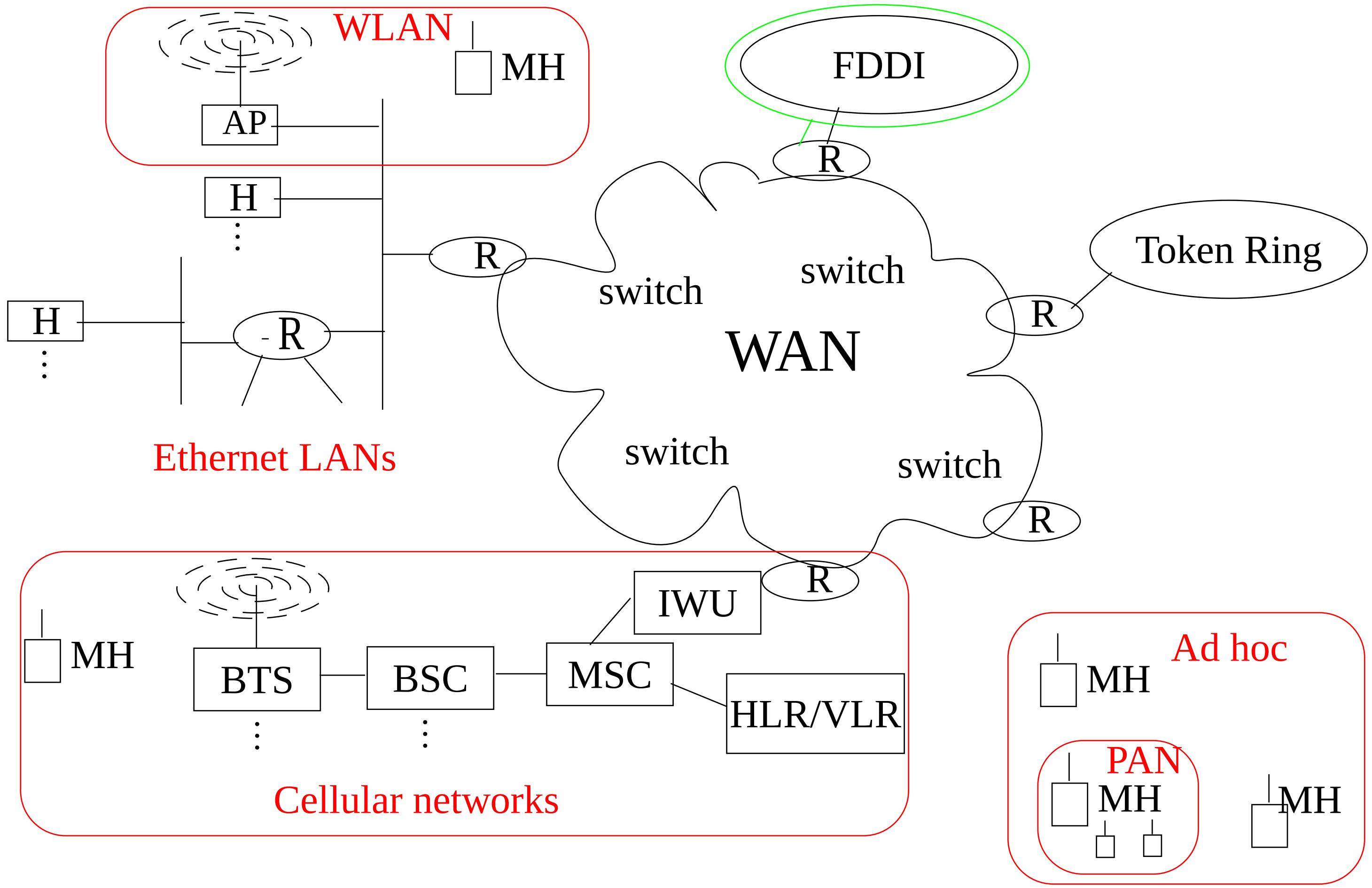


Figure 66: Mobility (WWAN, WLAN, PAN, …) driving us towards Mobile Internet

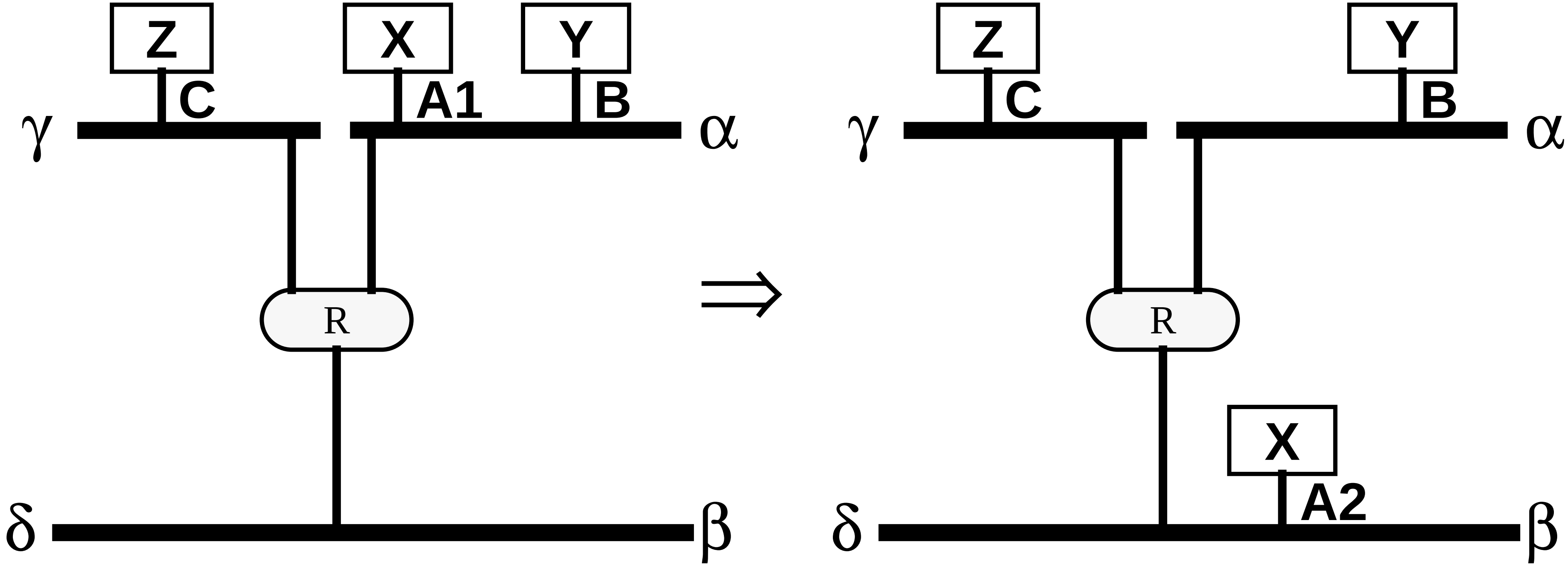


Figure 67. X disconnects from location A1 and reconnects at location A2

What is “X”? X represents the identity (ID) of the node.

- in an Ethernet it might be the MAC address, thus a node has a constant identity

While A1, A2, … represent the network addresses of node X.

- IP network address consists of {Network, Host}, i.e., A1={α | n}, where n is unique on network α.

Updating after a move

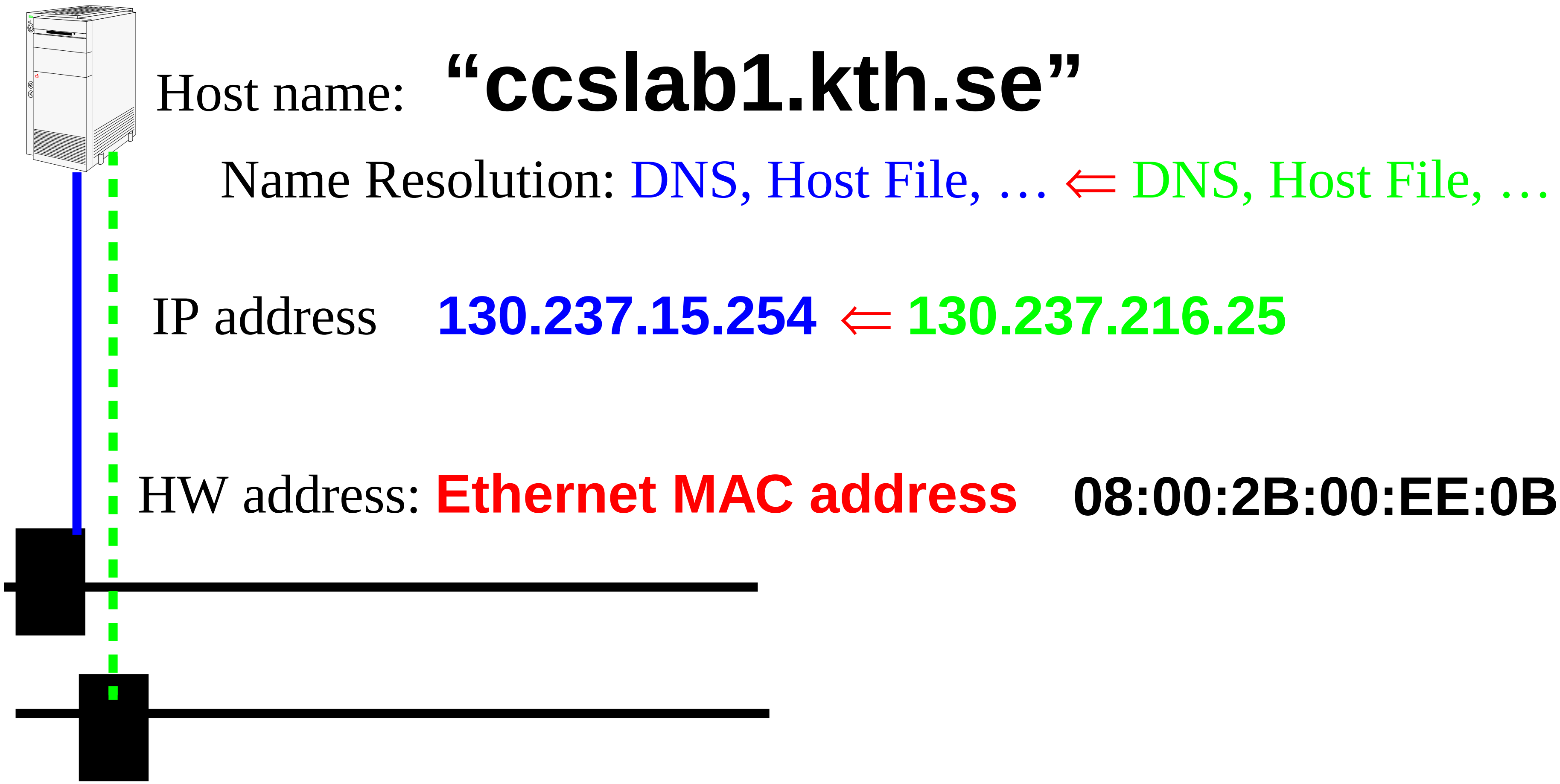


Figure 68: Must update IP address related mappings after a move ⇒ administrative nightmare

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

Communication from Z to X

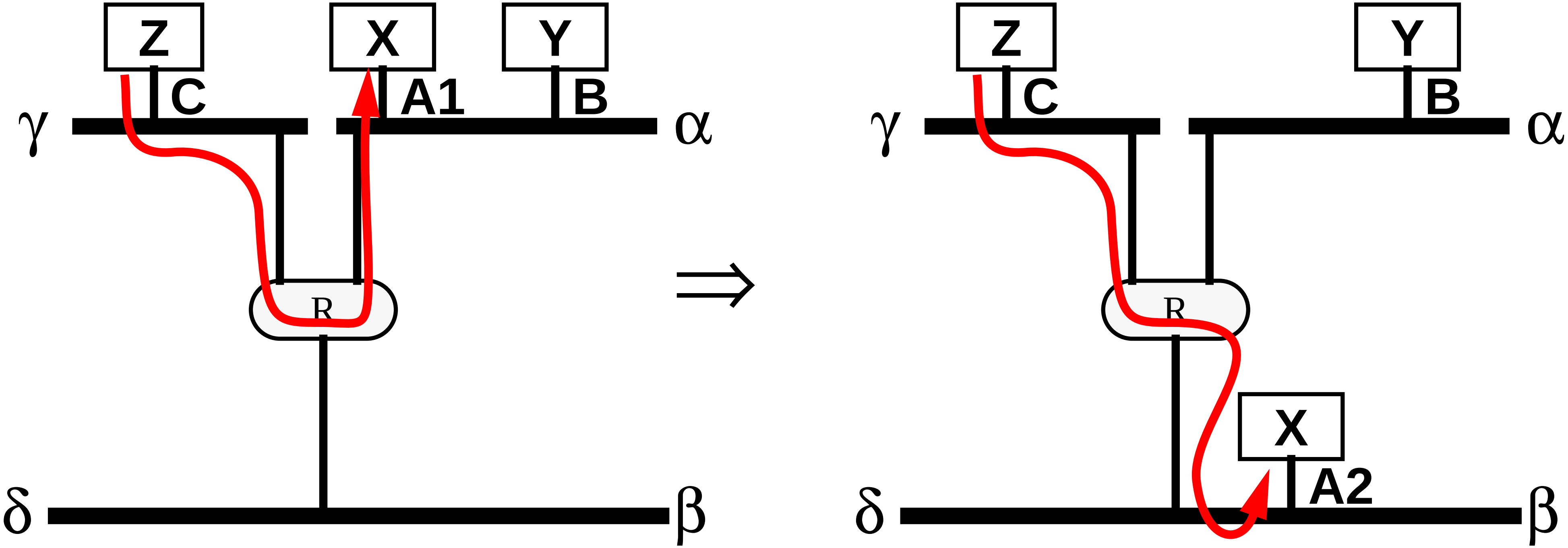


Figure 69. Z is communicating with X at A1 and wants to continue when X reconnects at location A2

- This would require that router R send packets from Z to X over a new path (route).
  - ✘ But X now has a new network address, since it is on a different network (β).

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[1] 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.

1. An informal experiment conduced 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!

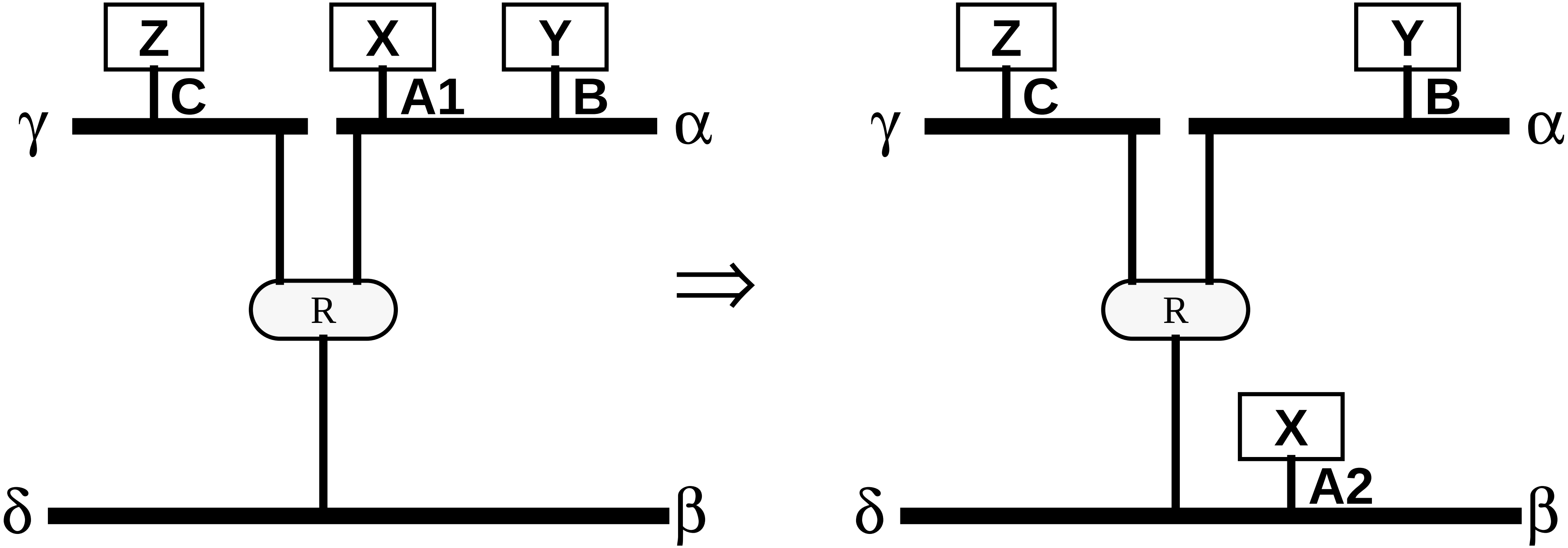


Figure 70. How do we know it is the same X?

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?)

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 MSR ≡ Mobility Support Router

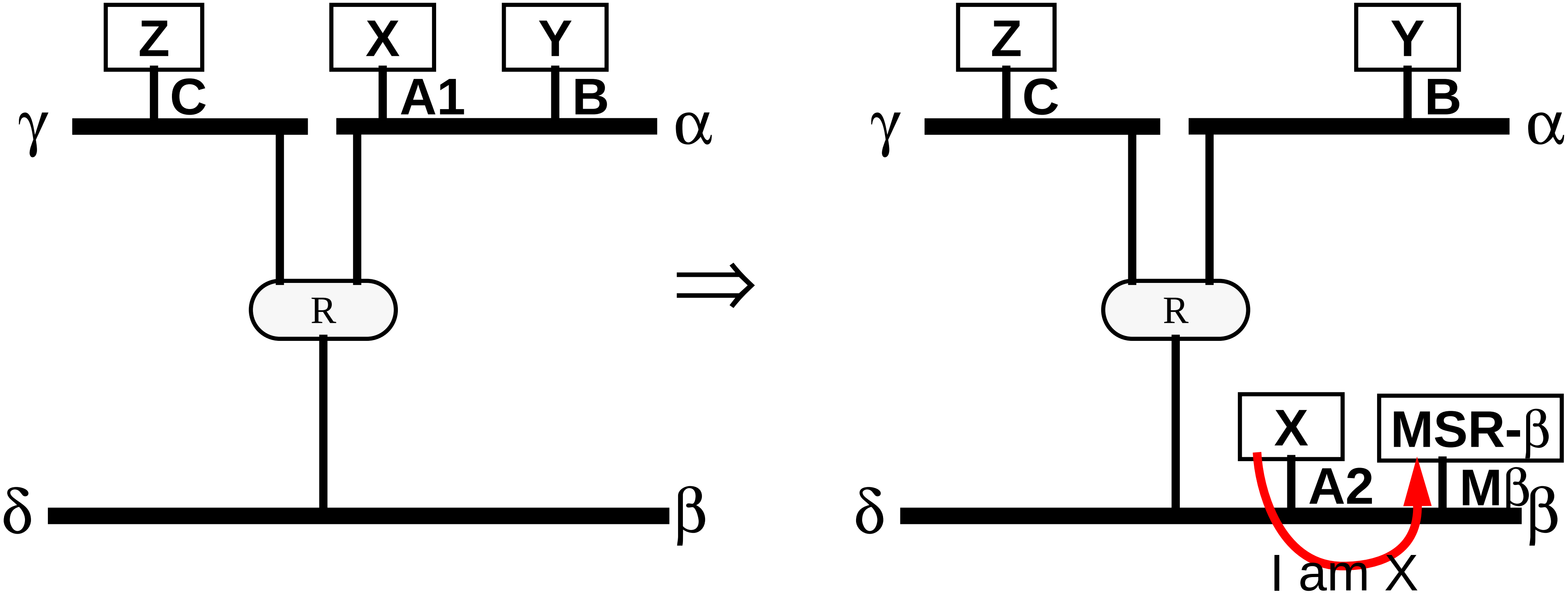


Figure 71. How do we know it is the same X?

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**

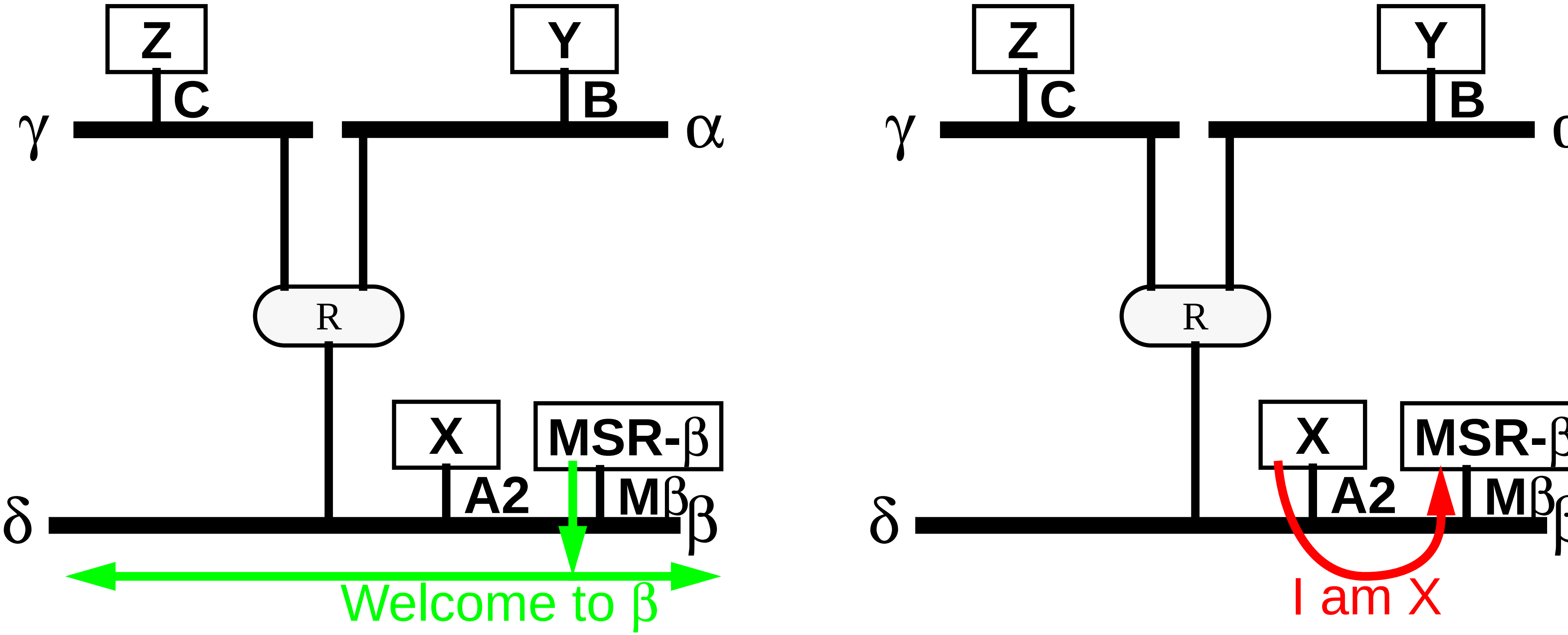


Figure 72. “Welcome (Greeting)” messages answered by “I am” messages

These broadcast “Welcome” messages advertise:

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

Could the MSR functionality be collocated with the router?

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

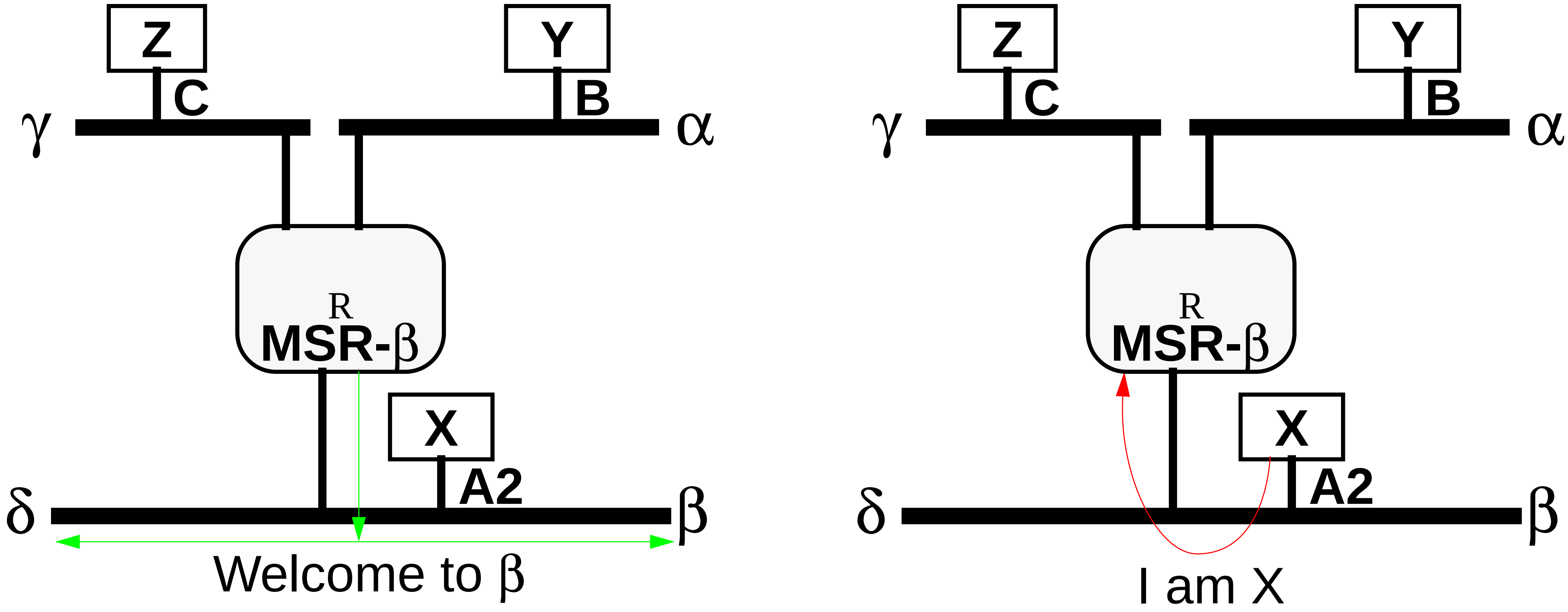


Figure 73. "Welcome (Greeting)" messages from router answered by "I am" messages

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

Getting Service

Once it's identity is know, the policy **question must be ask: 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 the topics of a recent thesis: 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.

See also IEEE 802.1x Port Based Network Access Control
http://www.ieee802.org/1/pages/802.1x.html

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

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

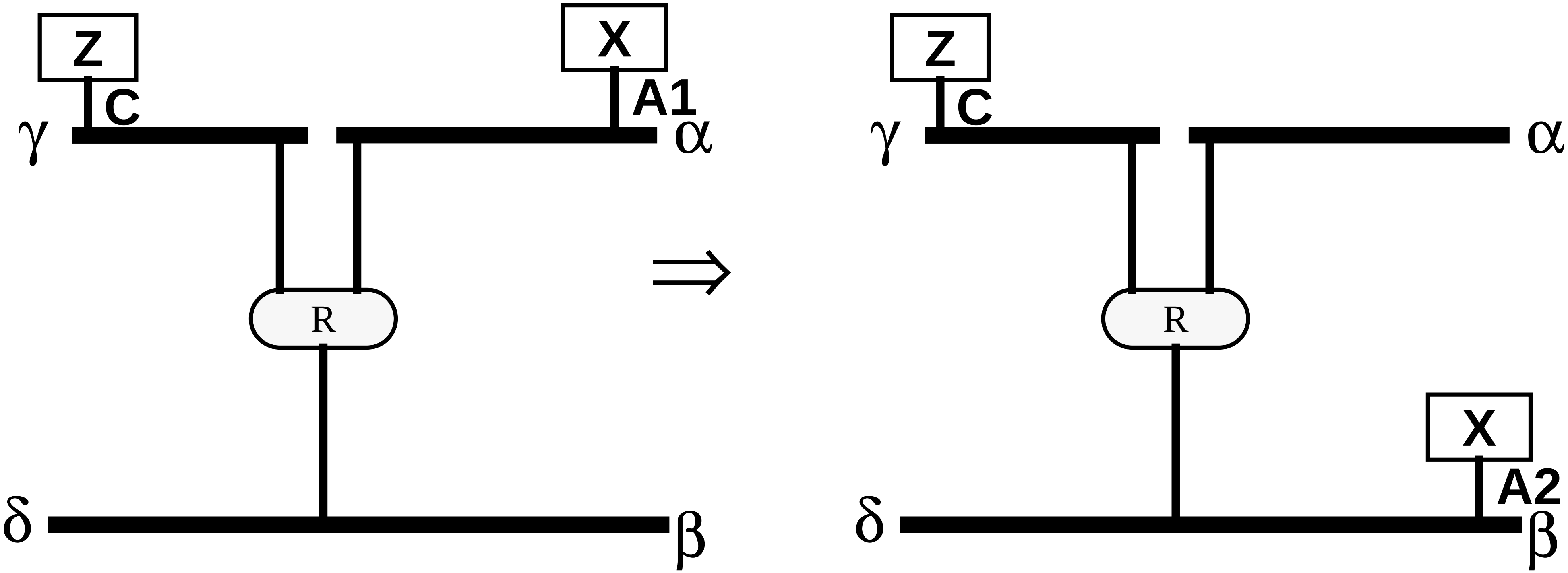


Figure 74. X moves from A1 to A2 (shown with the MSRs explicitly), Z not aware of Mobility

There are several alternatives.

Alternative 1

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

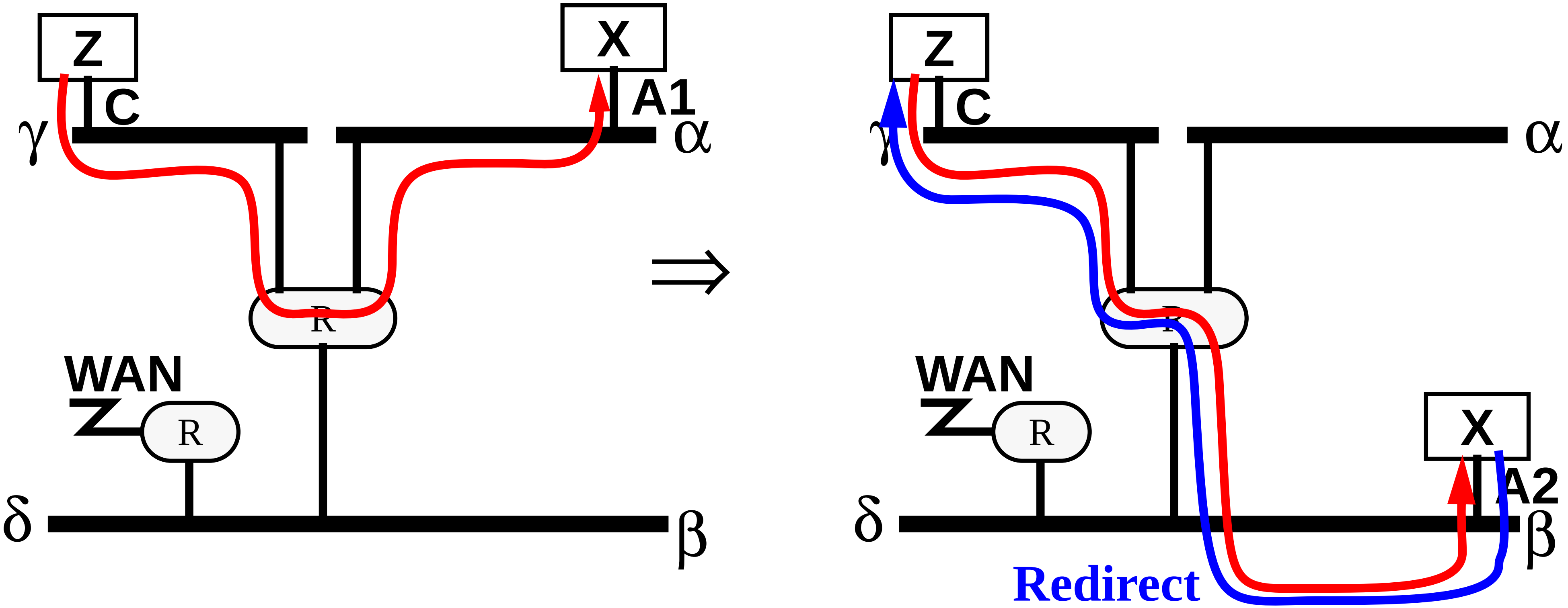


Figure 75. X must send a redirect message to Z, to tell it it's new address A2.

- ✘ Z must be aware of where X currently is.
- ✘ X must get a new local address A2 (How? perhaps DHCP)

Alternative 2

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

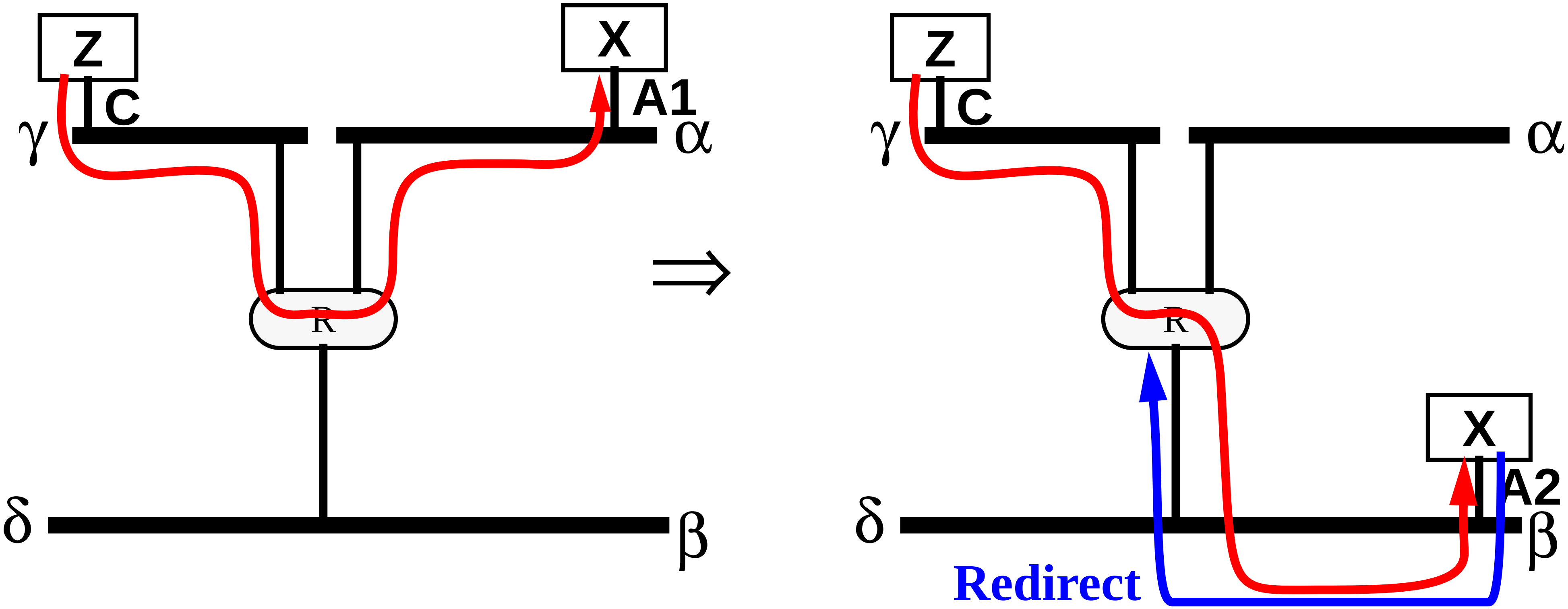


Figure 76. X must send a redirect message to the **Router**, to tell it it's new address A2 (rather than A1).

- ✘ Router must now perform host specific routing.
- ✘ X must get a new local address A2 (How? perhaps DHCP)

Alternative 3

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

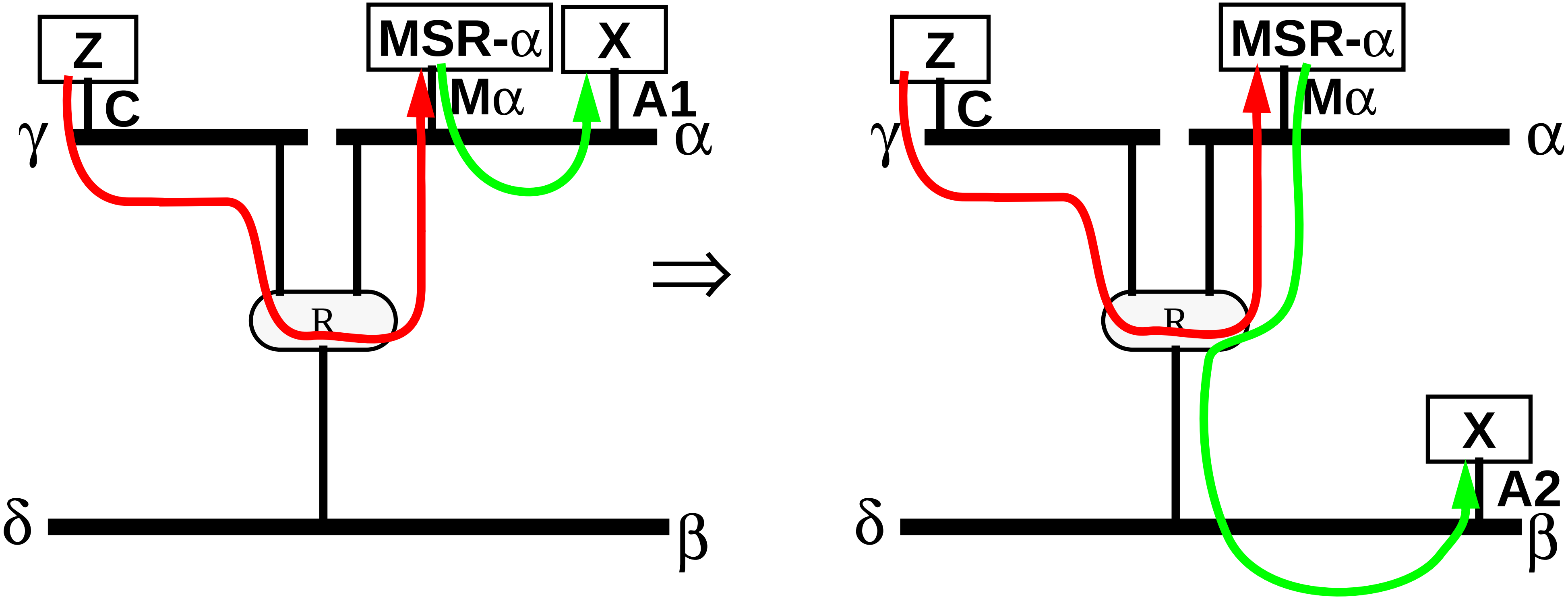


Figure 77. X must send a redirect message to a Mobility Support Router (**MSR-**α), to tell it it's new address A2 (rather than A1).

- ✘ **MSR-**α must now perform host specific routing.
- ✘ X must get a new local address A2 (How? perhaps DHCP)
- ✔ Z is now completely unaware of the move.
- ✔ Router R is now completely unaware of the move (except for twice the traffic over the link to/from α).

Alternative 4

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

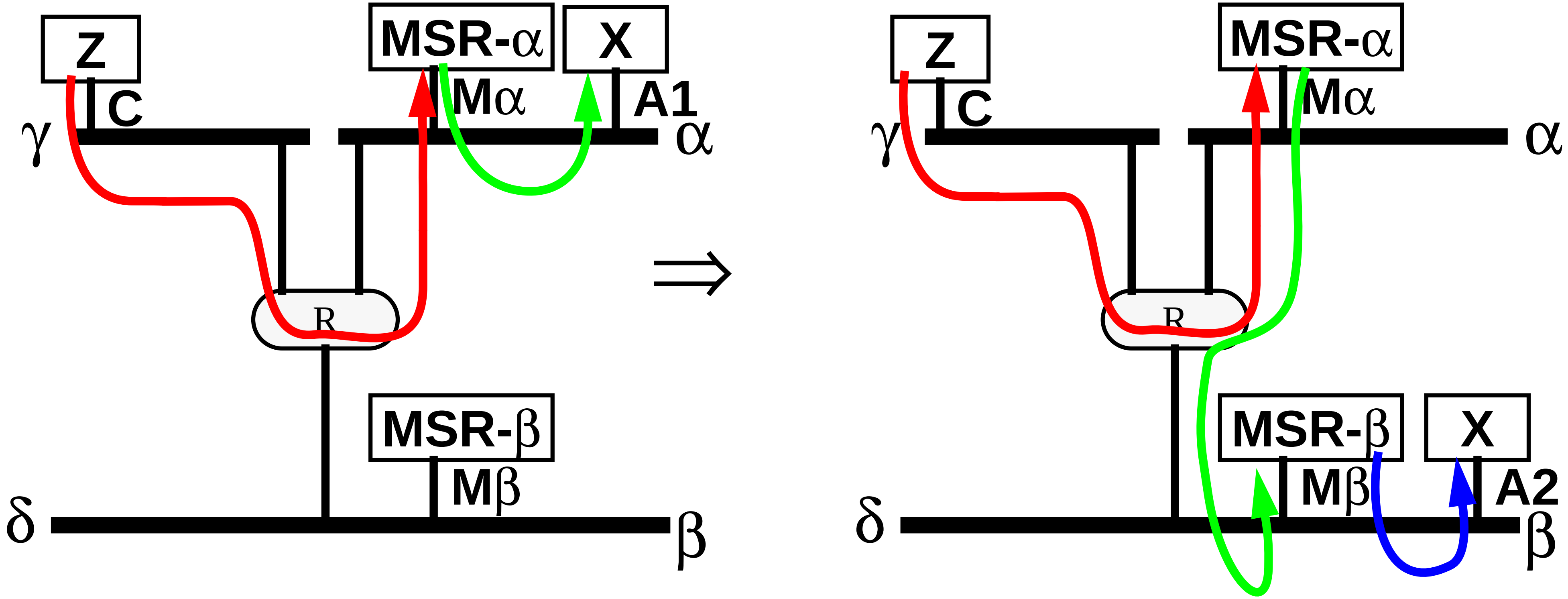


Figure 78. X sends a message to **MSR-β**, to get it's new address A2 and says it's old MSR was **MSR-α**.

- ✘ **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.

Alternative 4 continued

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

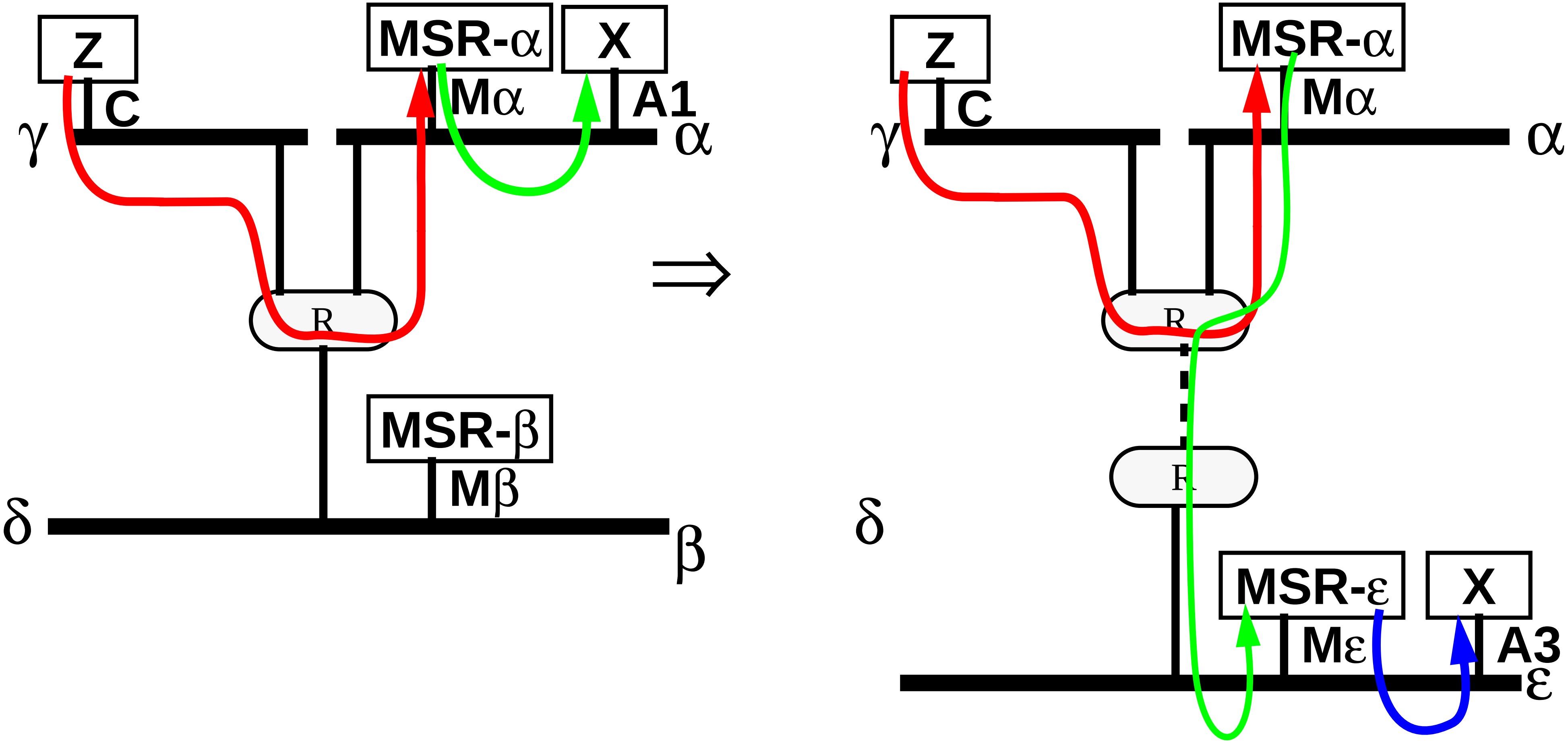


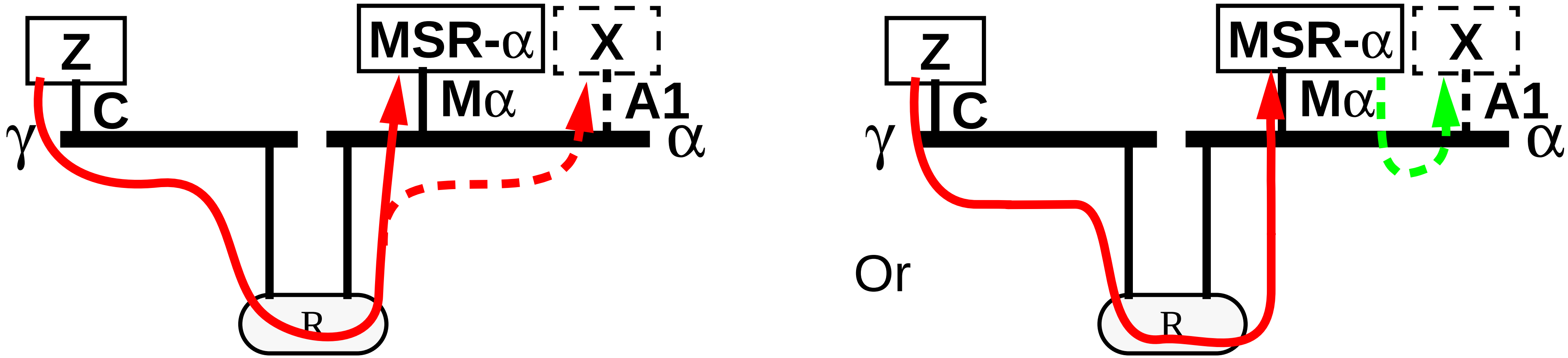
Figure 79. X sends a message to **MSR-ε**, to get it's new address A3 and says it's old MSR was **MSR-α**.

✔ 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 router needs to know about mobility.

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

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

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



- X's address is A1
- A1 is an address on network α
- MSA-α intercepts packets addressed to A1 and forwards them if X is not currently present on the network α

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

Figure 80. 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.

What happens in the case of wireless networks?

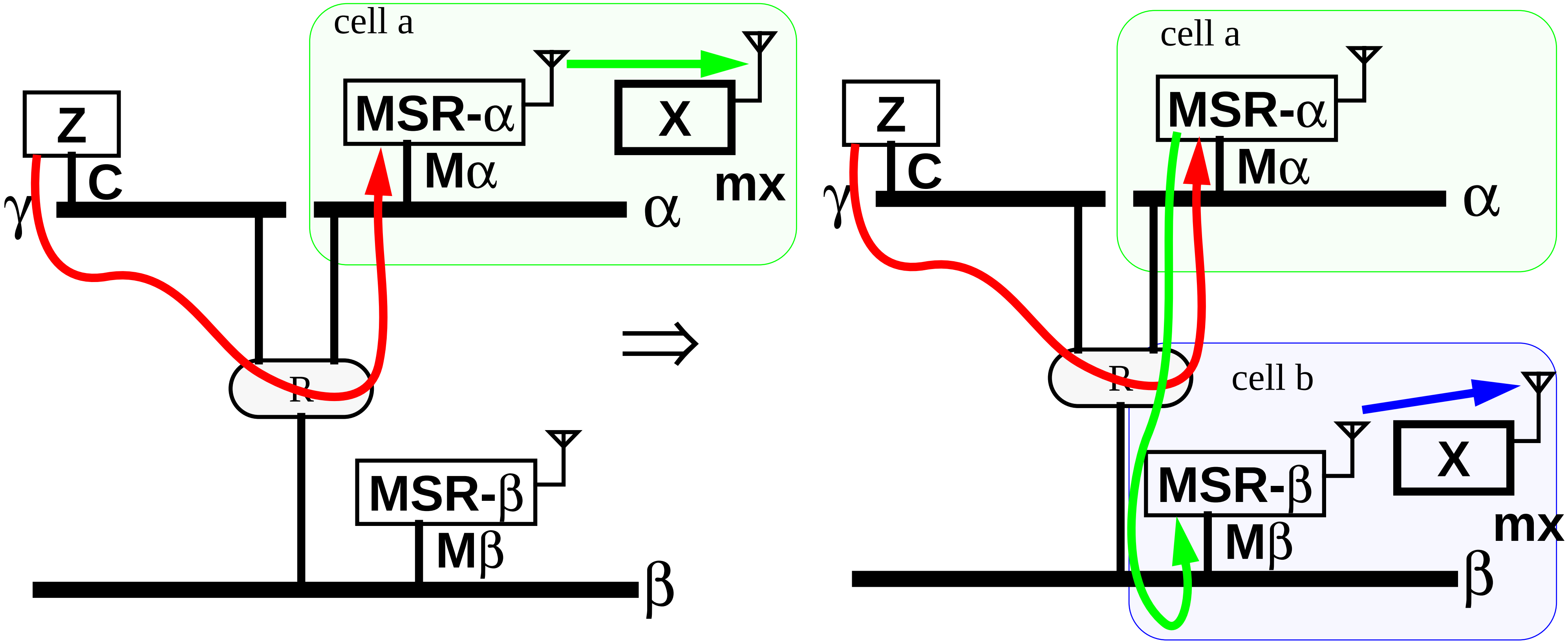


Figure 81. X moves from the cell a to the cell b

- The wireless cells are implemented by a basestation co-located with the MSR.
- Note that X retains it's mobile network address "mx".

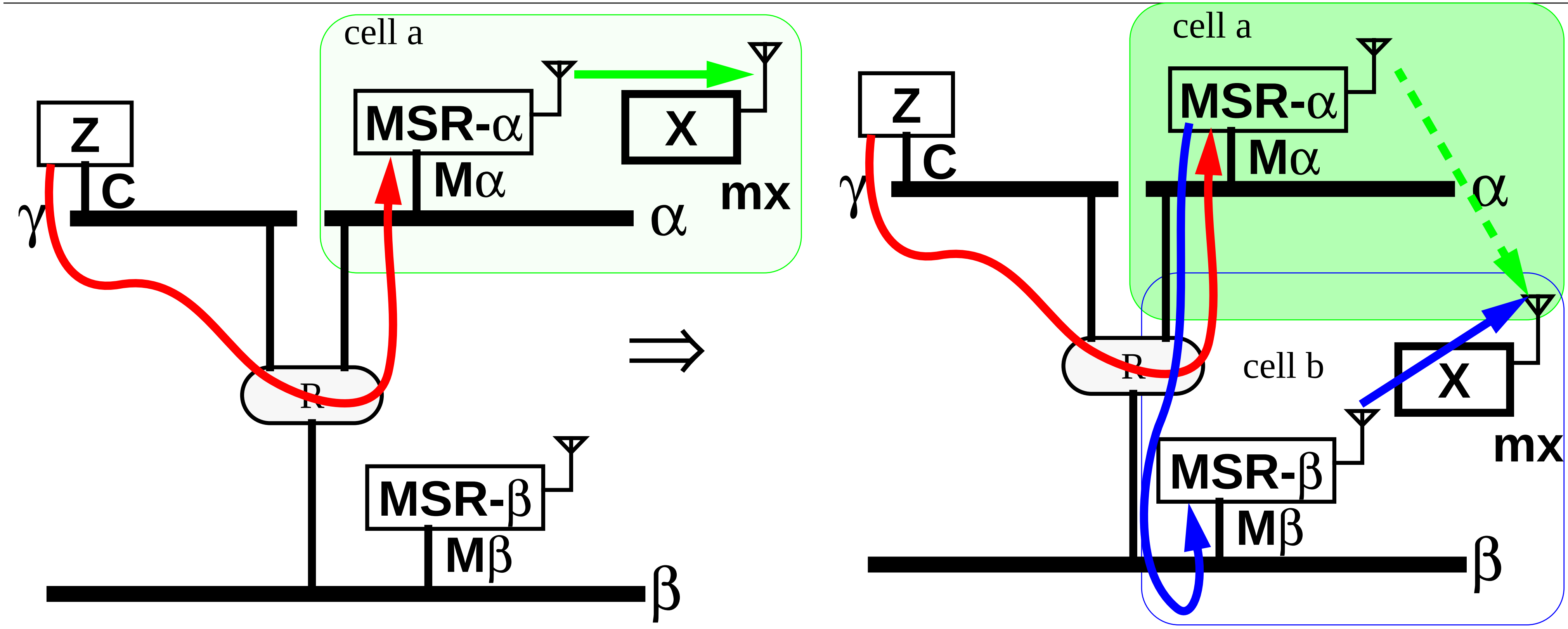


Figure 82. X moves from the cell a to the cell b, but is still **reachable by cell a**!

- Mobile network address “mx” is reachable from both MSR-α and MSR-β.
- This could not occur in the wired case (unless there were multiple interfaces), since X would have to disconnect from network α to connect to network β.
- If the cell size is small the movement between cells could be frequent (and caused by other events, such as a new user, a door moving, …).

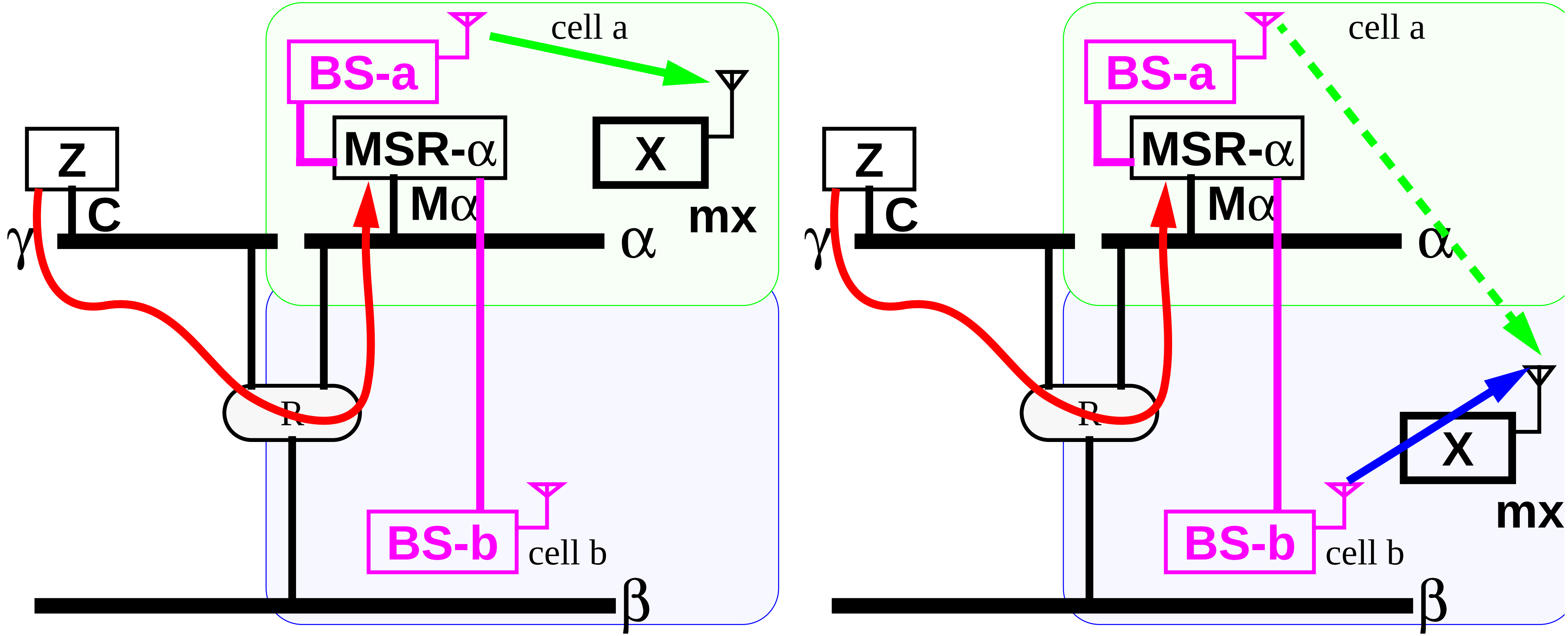


Figure 83. X moves from the cell a to the cell b, but may still reachable by cell a - but both cells are part of the same network

- 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.

Simulcasting in Wireless Local Area Networks

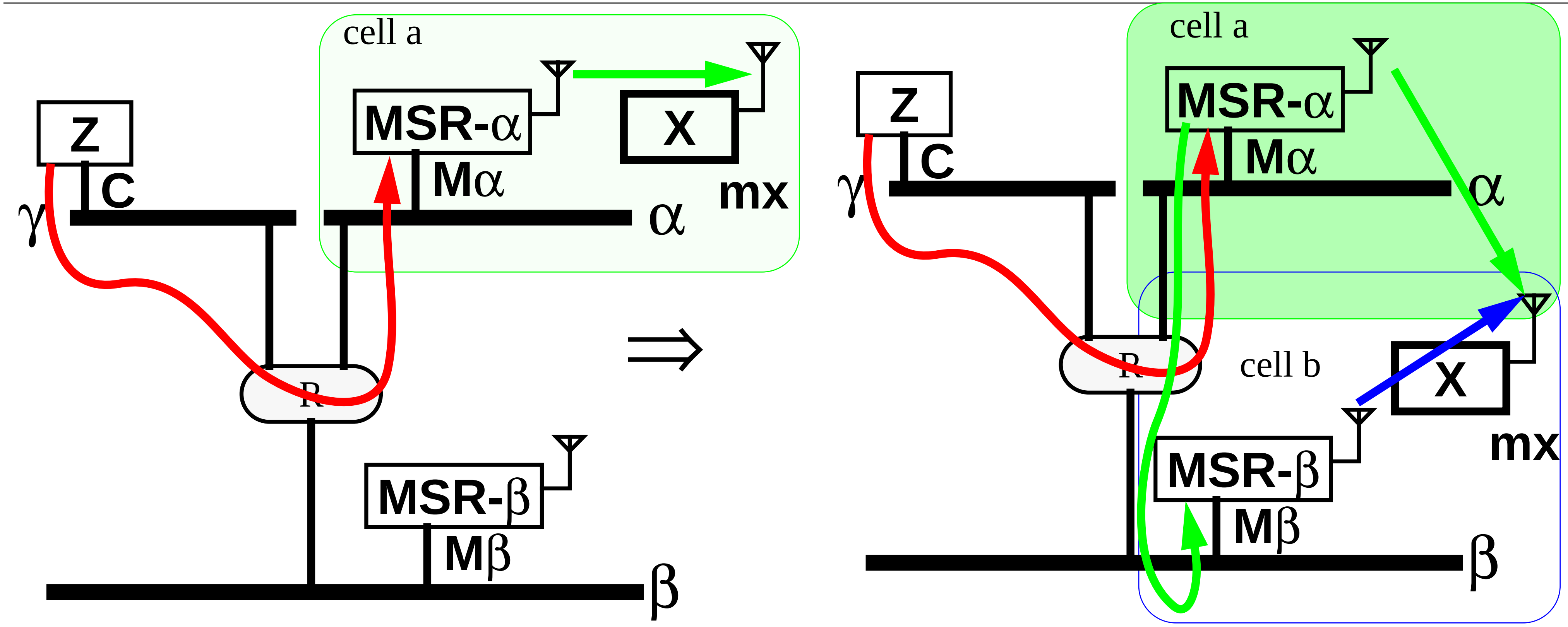


Figure 84. X is moving from the cell a to the cell b

- 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

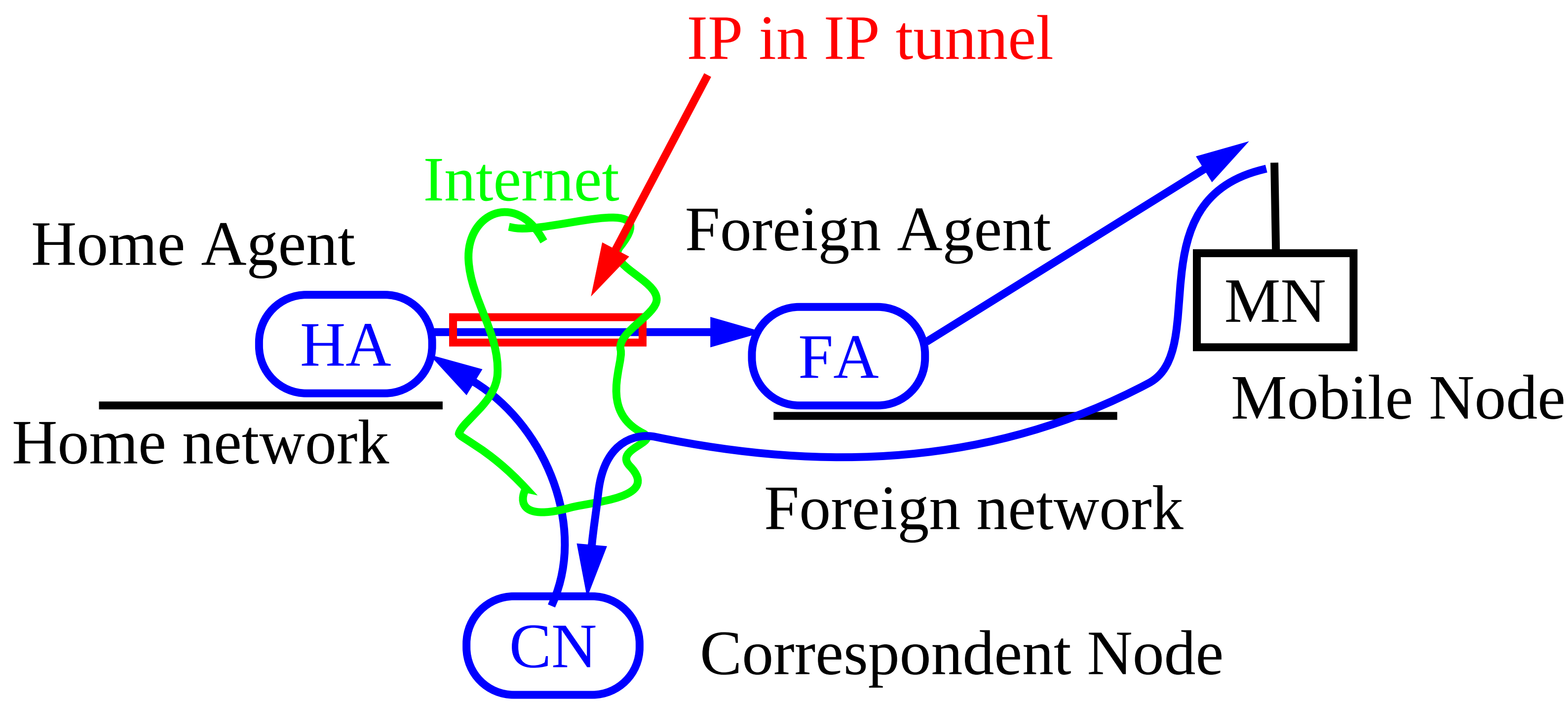
Mobile-IP Standard Effort

- Originally proposed by Columbia University, IBM, etc.
- Internet Engineering Task Force (IETF) Mobile-IP working group
  - *http://www.ietf.org/html.charters/mobileip-charter.html*

Current Mobile-IP standard status:

- RFCs:
  - Mobile-IPv4 (RFC2002) IP Mobility Support; RFC2003: IP Encapsulation within IP; RFC2004, RFC2005, RFC2006, etc.
  - Mobile-IPv6.
- 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.

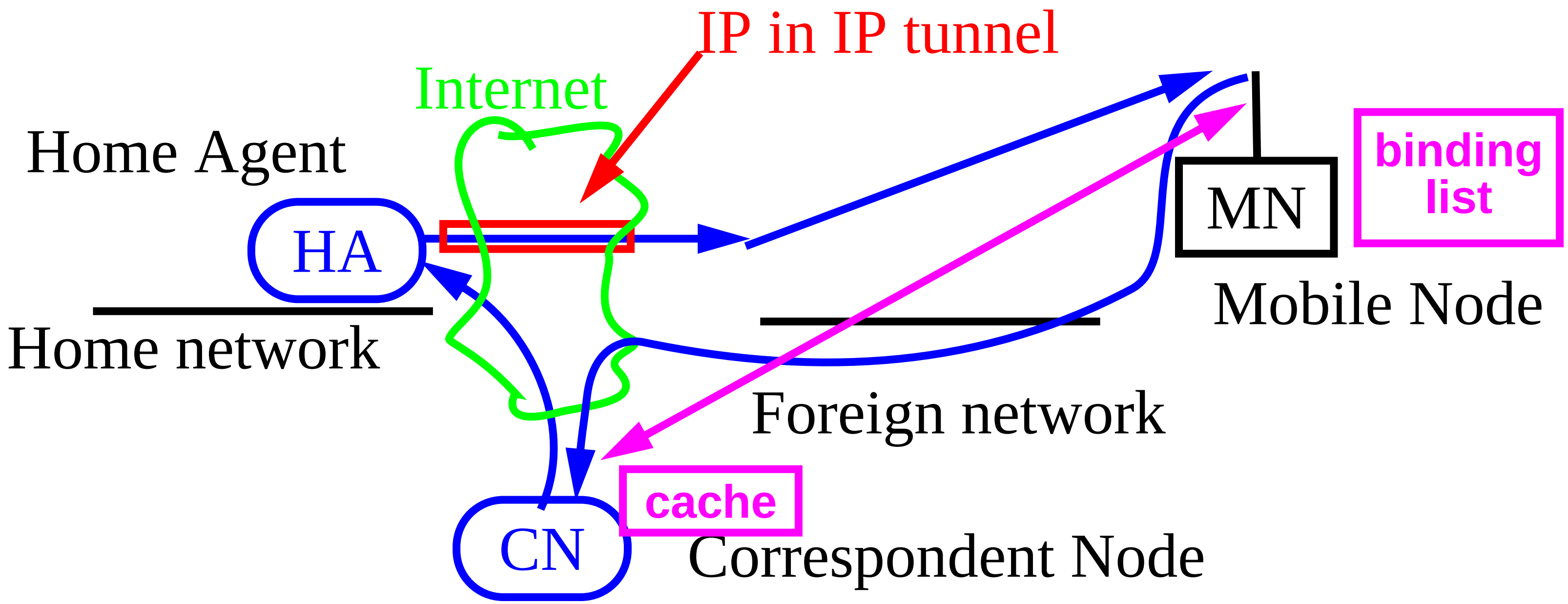
A Mobile-IP(V4) Scenario



CN sends packet to MN's home network (because that is where its IP address is logically located), HA intercepts them and forwards them inside an IP-in-IP tunnel to the Care of Address (CoA) where the FA forwards them to the MN.

Traffic from the MN can go directly to the CN (**unless** there is ingress filtering).

A Mobile-IP(V6) Scenario



CN sends packet to MN's home network (because that is where its IP address is logically located), HA intercepts them and forwards them inside an IP-in-IP tunnel to the Care of Address (CoA) which is the MN's address in the foreign network.

However, the MN can tell the CNabout its **current** address via a binding update (BU), now traffic can flow both ways directly between the CN and MN.

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.

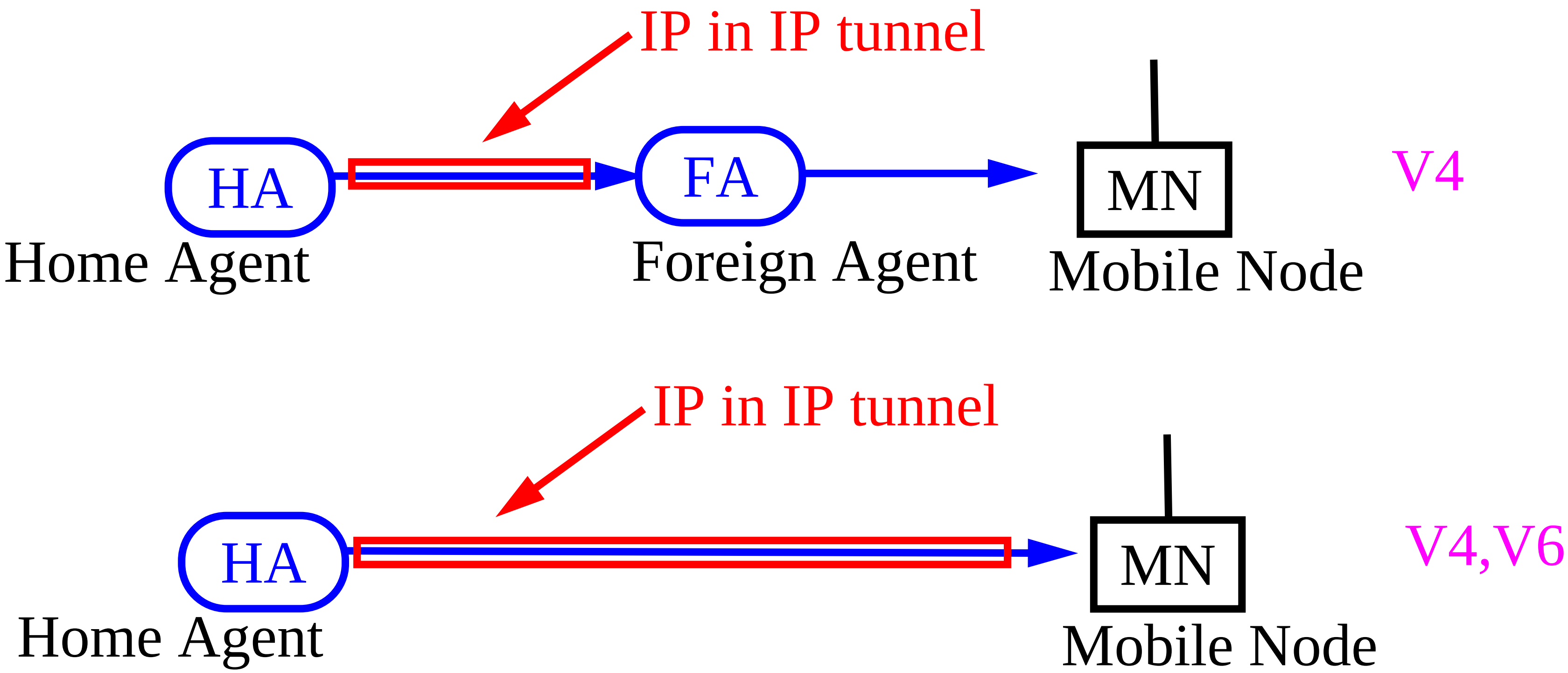
For details see

- IP Encapsulation within IP *RFC2003.*
- Minimal Encapsulation within IP *RFC2004*.

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:

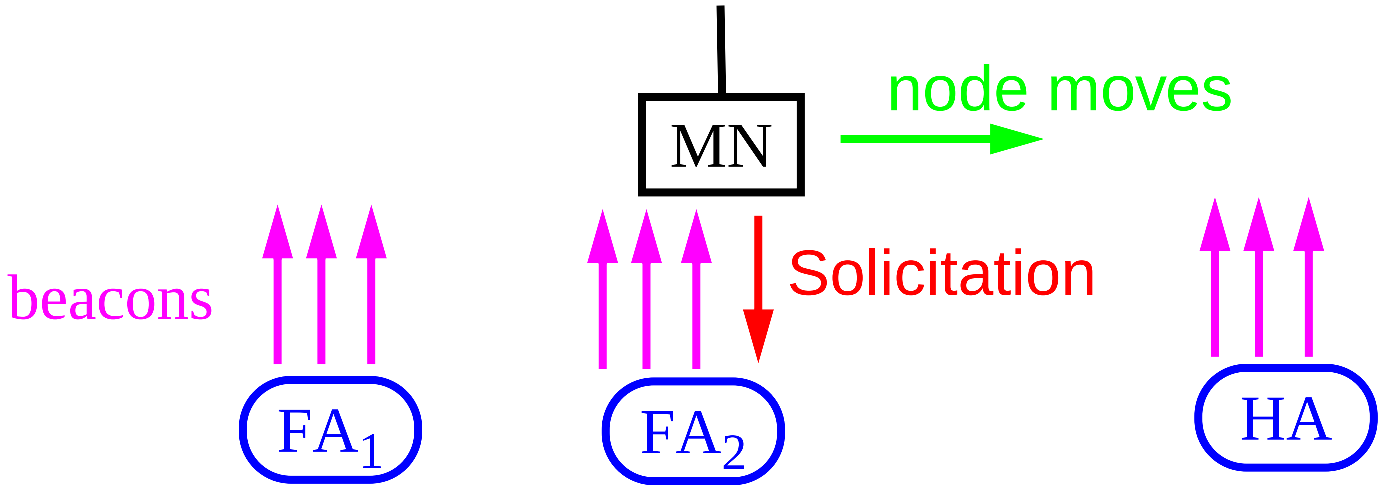
- Foreign agent care-of address (V4)
  - a care-of address provided by a foreign agent through its Agent Advertisement messages.
- Co-located care-of address (V4, V6)
  - a care-of address acquired by the mobile node as a local IP address through some external means, eg. dynamically acquired as a temporary address through DHCP (RFC1541, dynamic host configuration protocol), or the address may be owned by the MN as a long-term address for its use while visiting this foreign network.

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.



Agent Advertisement Message Format

Extension of an ICMP router advertisement

0	8	16	24	31
TYPE (16)	Length	Sequence Number		
Lifetime		CODE	Reserved	
Care of Address* {the number is determined by the length field; must be at least 1 of F bit set}				

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				

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)

MN Requirements

An MN must have:

- home address, netmask,
- 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:

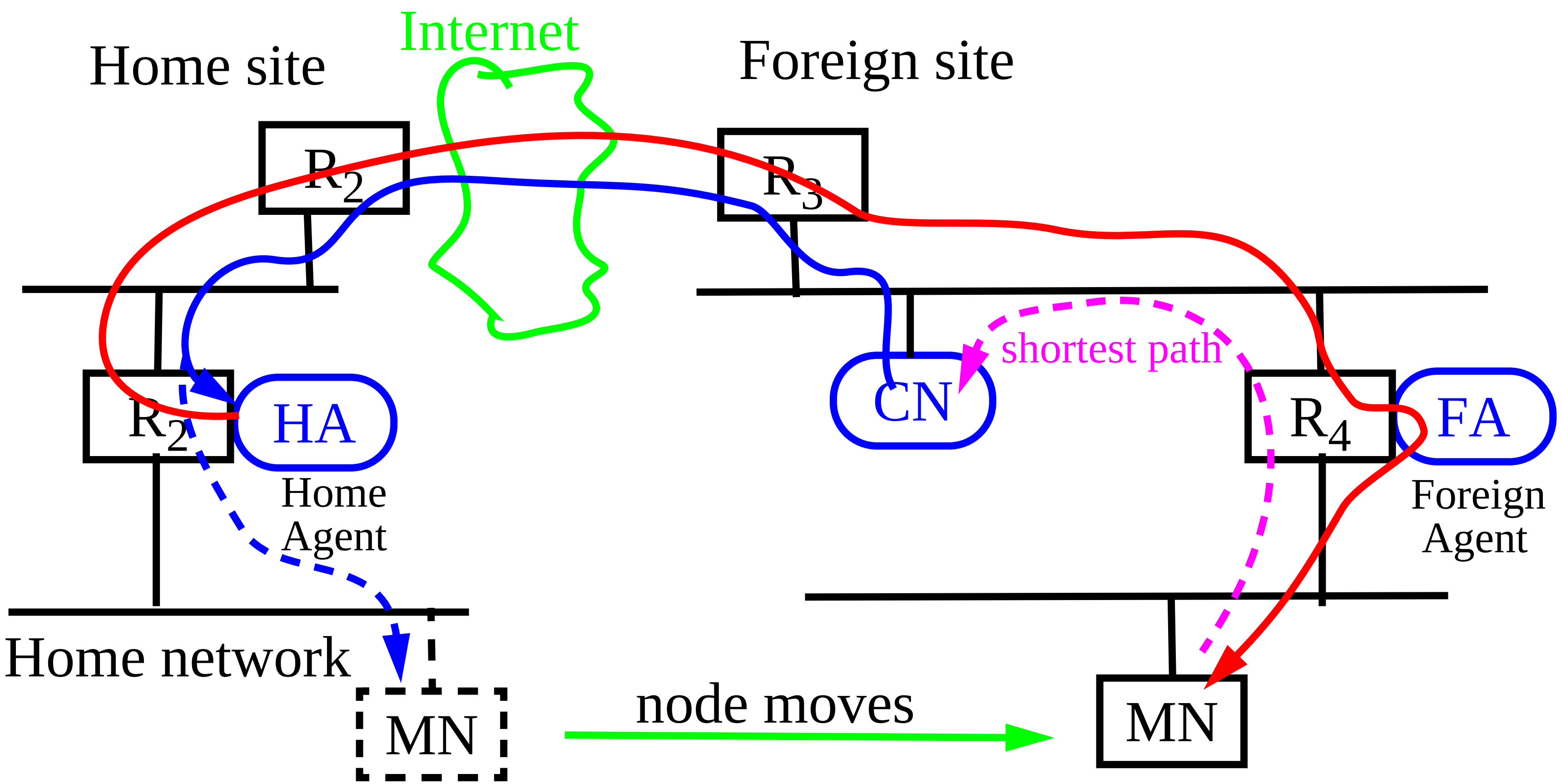
- the home address and mobility security association of each authorized MN that it is serving as a home agent.

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.

Optimization Problem



We can **not** follow the shortest path in Mobile IPv4 because the CN will always send it via our home network. However, we may be able to use the shortest path from the MN to the CN.

Problems of Mobile IP (RFC2002)

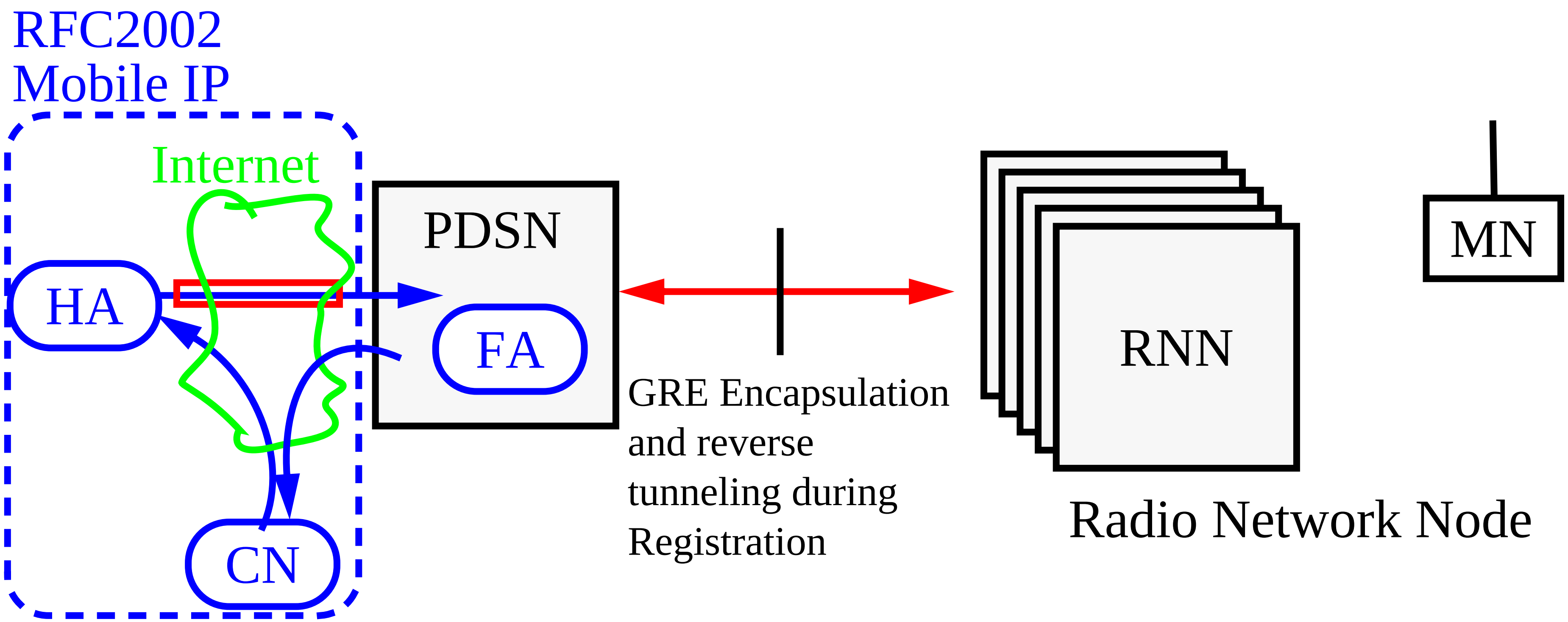
• Only provides basic "macro mobility" support • Not developed for cellular systems • No interface defined between cellular systems • (e.g. between Mobile-IP/HLR/VLR) • No handover support	}	⇒ Cellular Micro Mobility
• Weak in security • No key distribution mechanism	}	Security
• Route optimization problems	⇒	Optimization
• No QoS, real-time support, (DiffServ, RSVP)	⇒	QoS and Real-time
• …		

Mobile IP Problems and Development

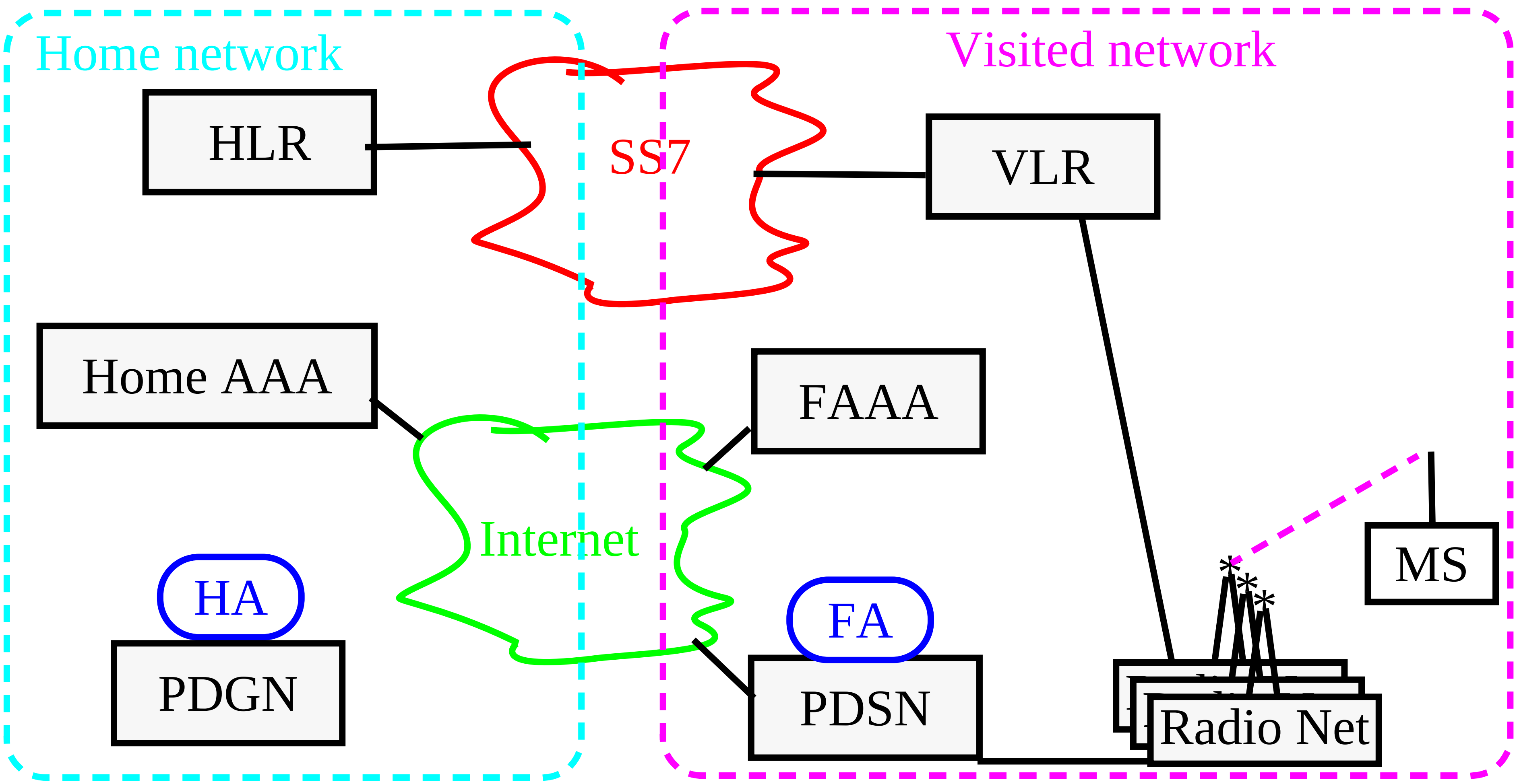
- Cellular Micro Mobility:
  - CDMA2000 Extension to MIP
  - Cellular IP
  - Regional Tunnel Management
  - Hierarchical MIPv6 Handoffs
  - MIP based Micro Mobility Mgt
- Security:
  - Mobile IP NAI Extension
  - AAA Registration Keys for MIP
  - Registration Keys for Route Optimization
  - Mobile IP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

CDMA2000 Extension to Mobile IP

A draft entitled: Mobile IP Based Micro Mobility Management Protocol in the Third Generation Wireless Network, by 3Com, Alcatel, Cisco, Ericsson, Lucent, Nortel, Motorola, Samsung, etc.

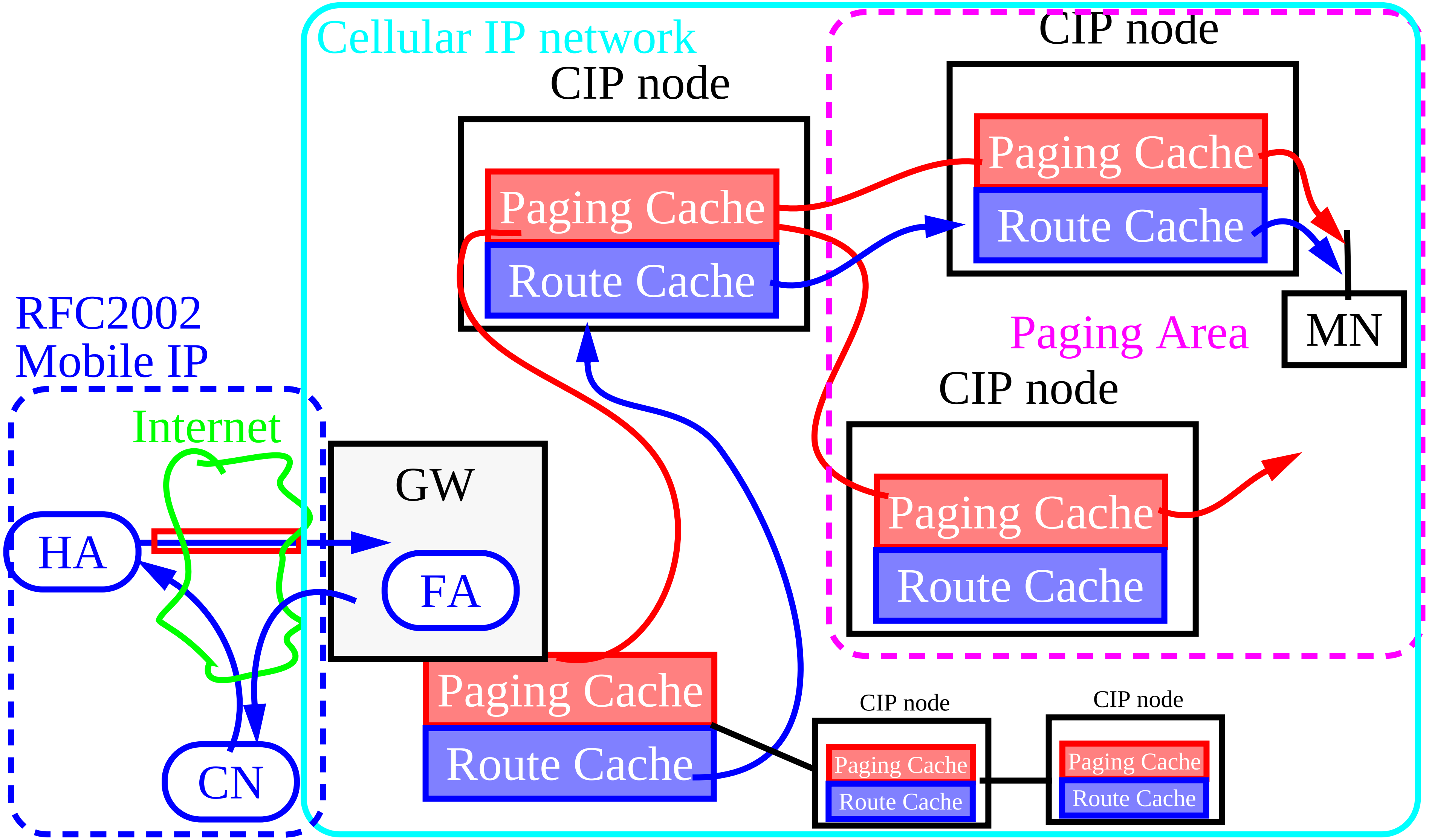


Wireless IP Network Architecture



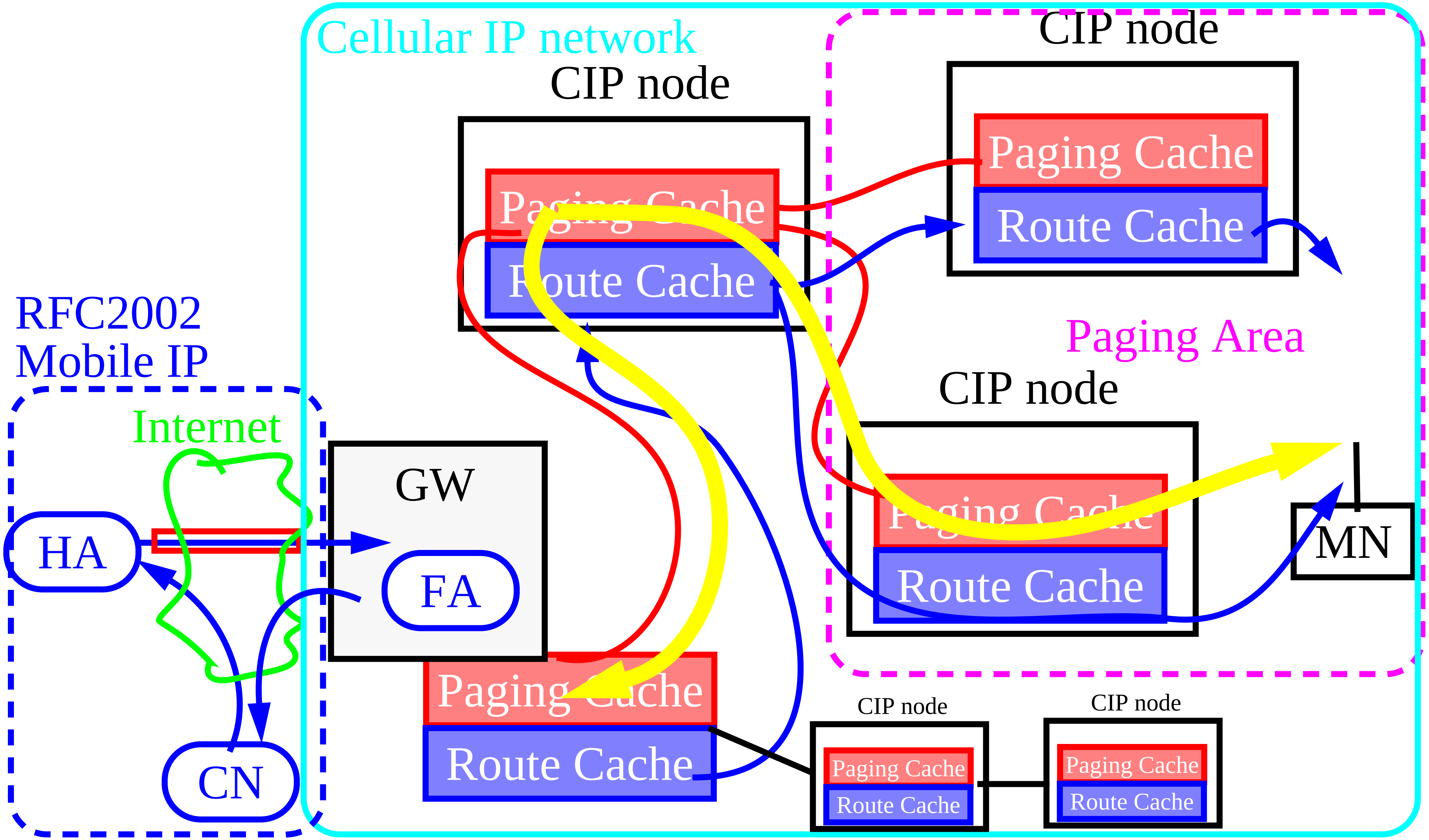
Cellular IP (CIP)

HAWAII extension is similar to Cellular IP.



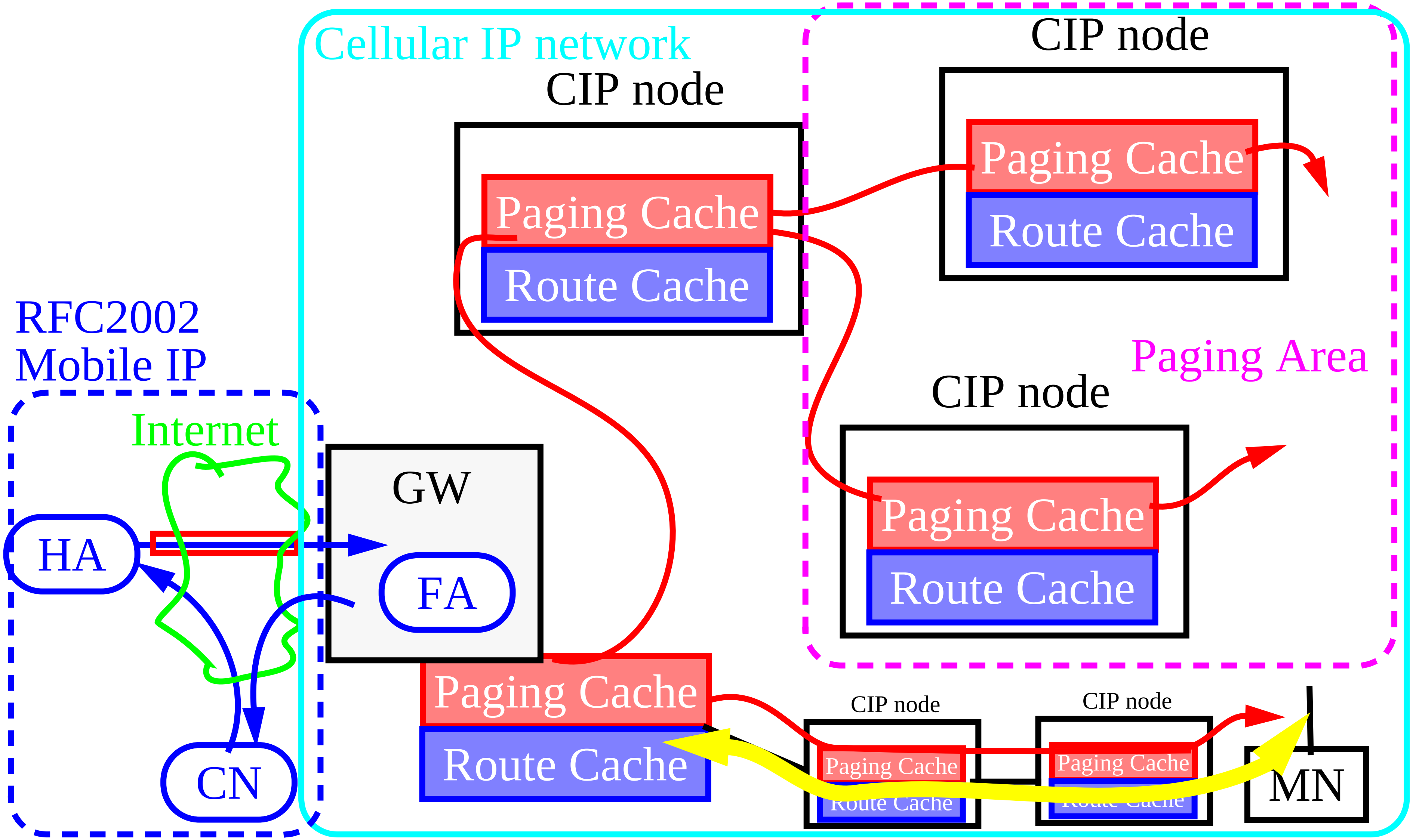
Cellular IP (CIP): Handover

HAWAII extension is similar to Cellular IP.

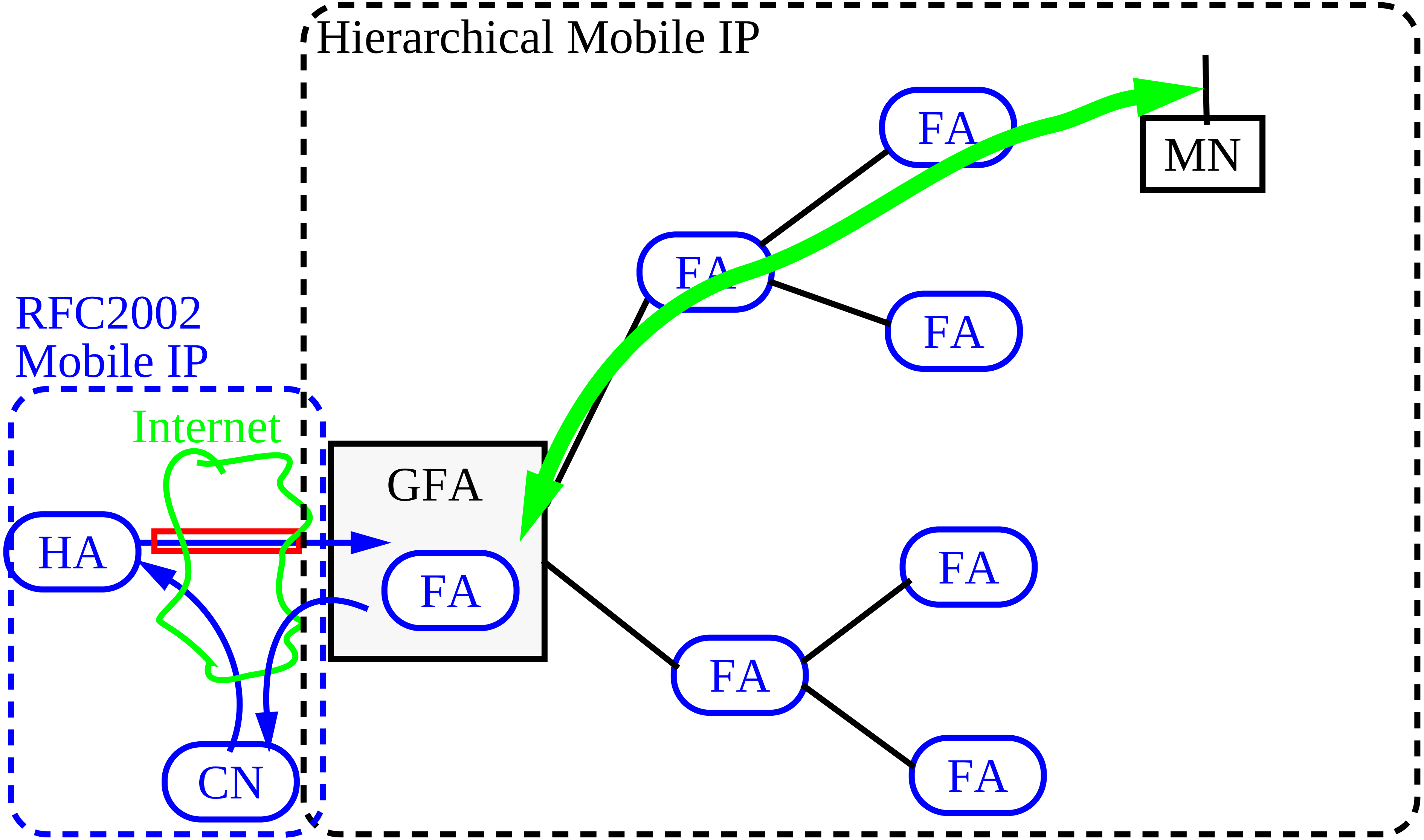


Cellular IP (CIP): Location Update

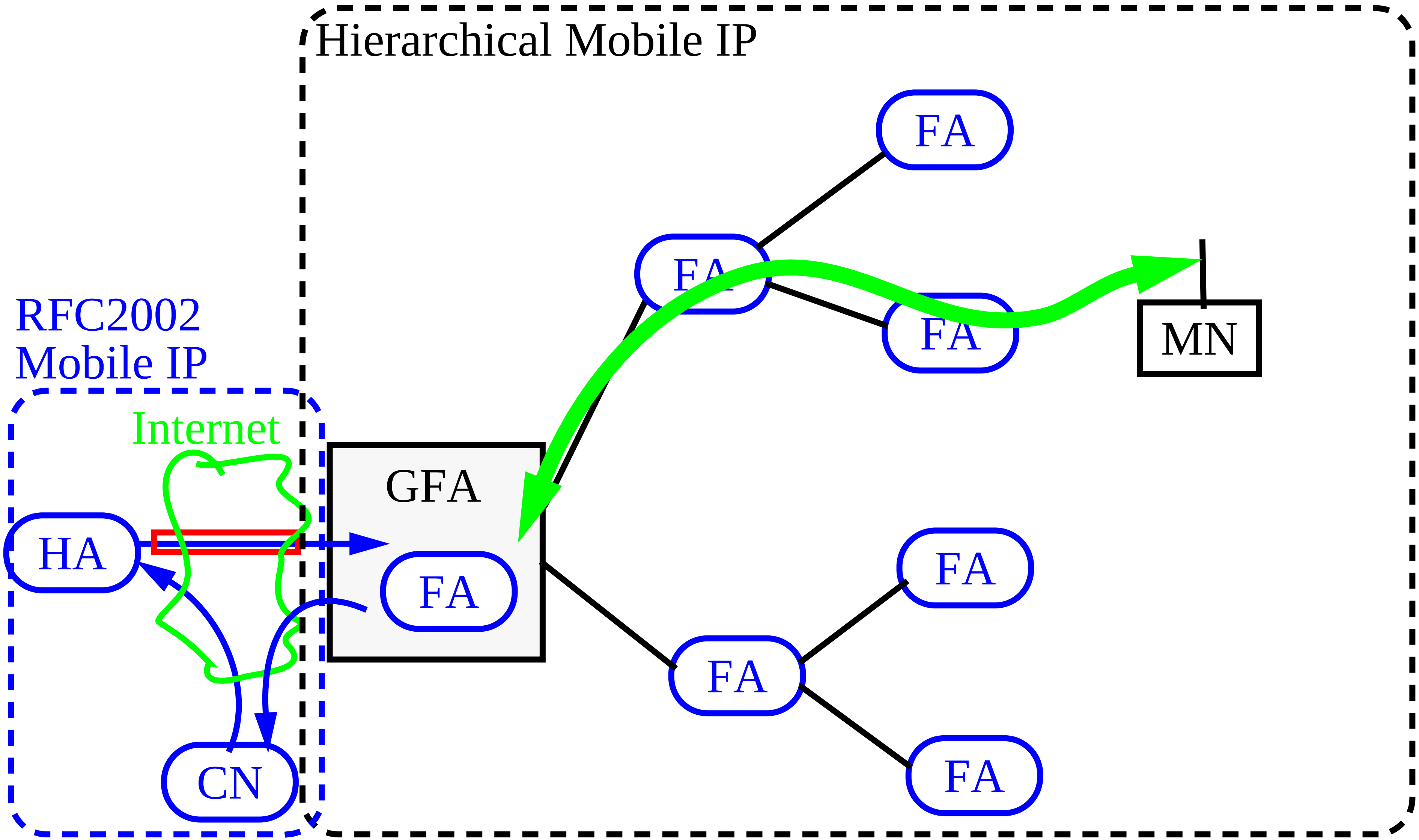
HAWAII extension is similar to Cellular IP.



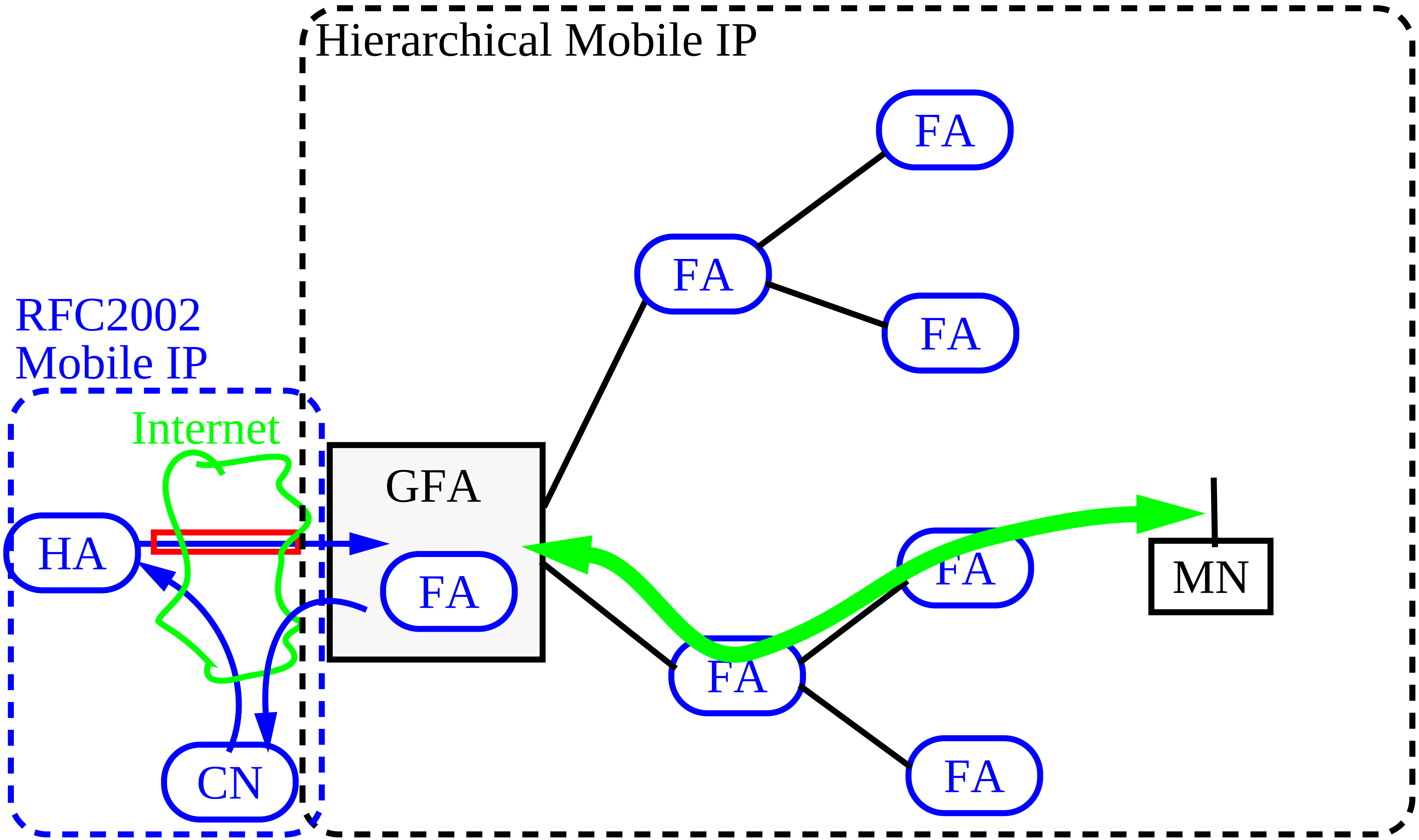
Hierarchical FA and Regional Tunneling



Hierarchical FA and Regional Tunneling



Hierarchical FA and Regional Tunneling



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.

Quality of Service (QoS)

QoS refers to statistical performance guarantees that a network can make regarding packet loss, delay, throughput, and jitter.

Best effort delivery means no QoS guarantee.

QoS is thought to be more and more important this days.

Many proposals, implementations and studies.

Does Internet need QoS? How can IP network provide it?

Service Differentiation

Integrated Services (InteServ):

- RSVP: connection request
- All nodes IntServ-capable
- Scalability
- Complicated network management

Differentiated Service (DiffServ): end of one-size-fits-all

- Classes of Service
- QoS based Routing
- Classes of Service at Gigabit rates
- New Pricing and Billing Policies
- New Resource Allocation Methods

See: *Differentiated Services for the Internet* by Kalevi Kilkki, Macmillan Technical Publishing, 384 pages, June 1999, ISBN: 1578701325.

Constraint-based Routing

QoS routing: selects network routes with sufficient resources for the requested QoS parameters

- to satisfy the QoS requirements for every admitted connection;
- to achieve network efficiency in resource ultilization.

Policy-based Routing: e.g. Virtual Private Networks (VPN)

How can we combine this with IP mobility?

Performance

Routers:

1/2 to 1 Million packets per second (pps) for every gigabit per second of aggregate bandwidth

more than 250,000 routes

PC interfaces

Standard I/O ports of coming PCs:

- Version 2.1 PCI bus - 64 bit, 66MHz, can burst to 528 Mbps
- Universal Serial Bus (USB) at 12Mbps - with plug and play
- Firewire™ (IEEE 1394) - supporting more than 400 Mbps
- Accelerated Graphics Port
- 10/100 Ethernet

Fibre Channel

From the X2T11 standards activity

Topologies: Point-to-Point, Fabric, and Arbitrated loop

Addresses: Loops, LANs, and worldwide addresses

Fibre Channel Profiles

Fibre Channel products

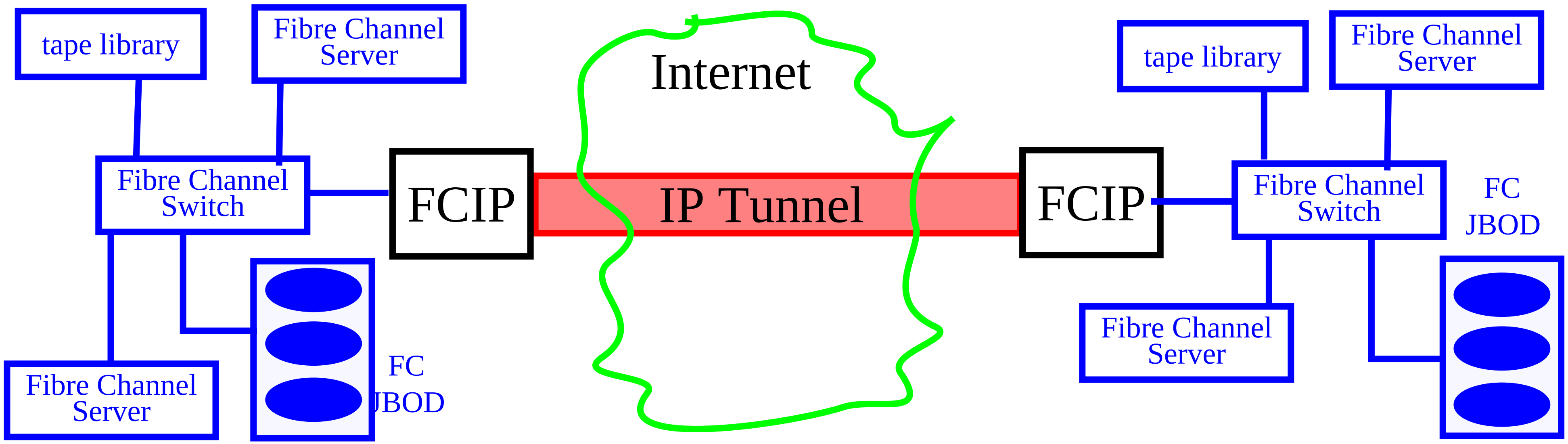
- Disk drives
- Network interfaces

IP Storage Area Networks (SANs)

Using IP in conjunction with storage:

- Fibre Channel Over IP (FCIP)

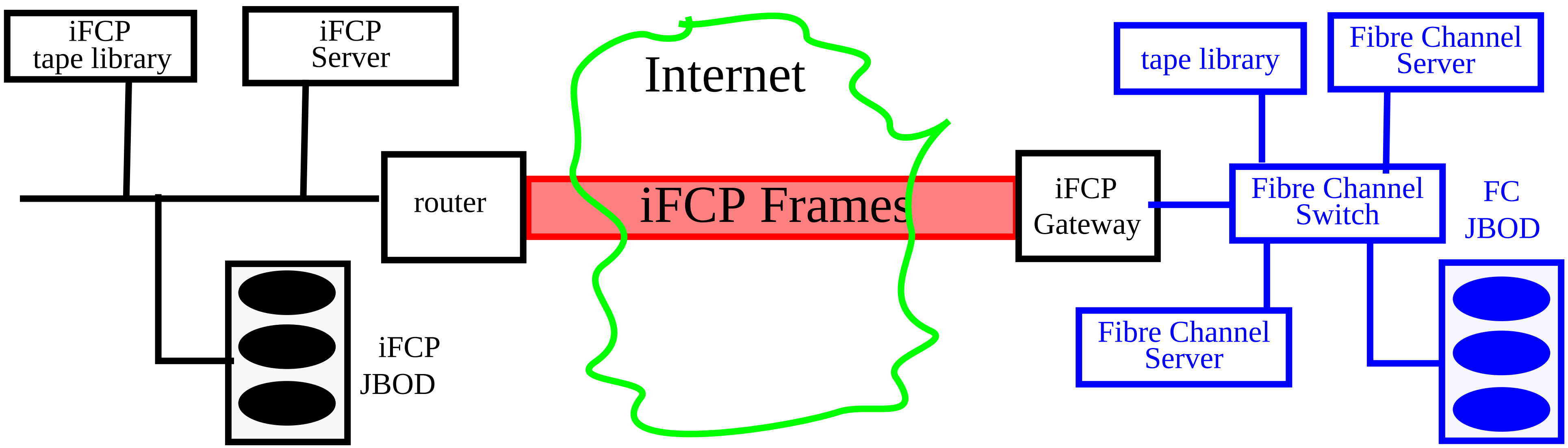
JBOD == Just a Bunch of Disks



Note that this approach simply interconnects the two Fibre Channel switches. The connection between the two switches is TCP and it simply encapsulates a FCIP header and a Fibre Channel Frame.

- Internet Fibre Channel Protocol (iFCP)

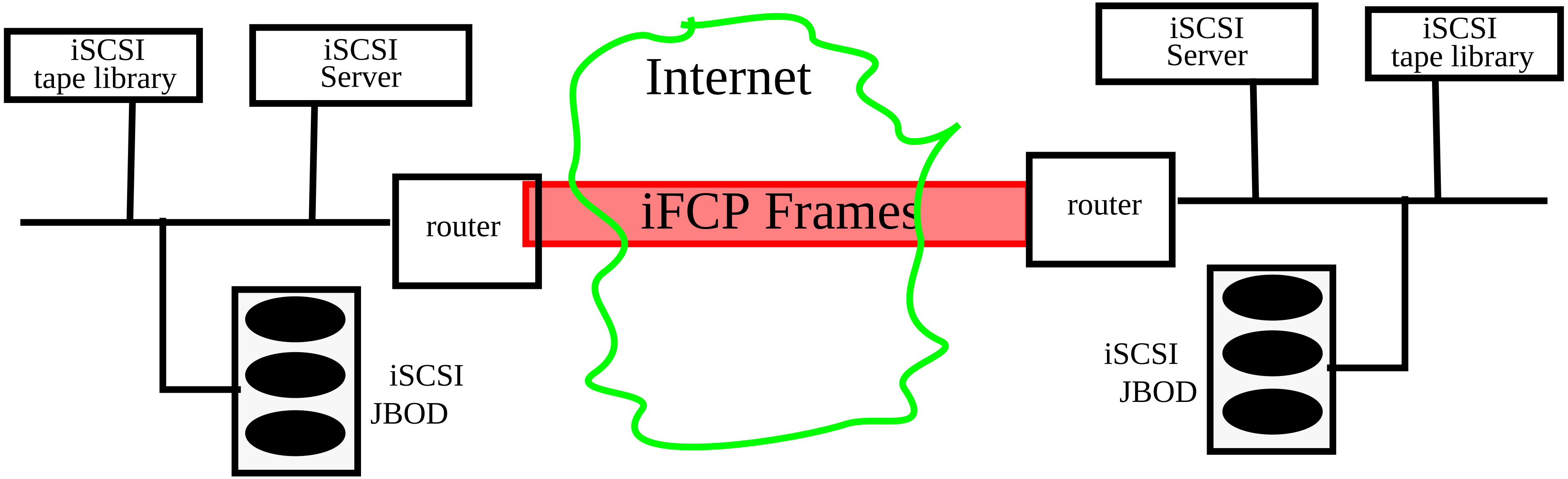
JBOD == Just a Bunch of Disks



Note that this approach interconnects Fibre Channel devices. The connection between the two switches is TCP and it encapsulates a iFCP header and a Fibre Channel Frame; note that iFCP devices can simply be attached to the internet or an intranet. This means that there has to be a mapping between Fibre Channel addresses an IP addresses.

- Internet SCSI (iSCSI)

JBOD == Just a Bunch of Disks



One a SCSI initiator has logged-in to a SCSI target, it can simply issue SCSI commands, just as if the device were on a local SCSI chain!

For more information see: *IP SANS: A Guide to iSCSI, iFCP, and TCIP Protocols for Storage Area Networks* by Tom Clark, Addison-Wesley, 288 pages, 2002, ISBN: 0-201-75277-8.

Clustering

Myricom, Inc.

Started by Prof. Charles L. Seitz - Caltech, now President and CEO

Dr. Robert Felderman - Director of Software Development

Mr. Glenn Brown - Engineer and programmer

Clusters used to form high performance servers, using commodity networks and hosts.

Virtual Interface Architecture

Distributed Supercomputer Supernet (SSN)

Uses OPTical Interconnect of MyriNet IC (OPTIMIC) chips to create a high performance network using Myricom asynchronous pipeline crossbars (APC) interconnected by a WDM optical backbone.

“Beowulf-class” machines

Using large numbers of commodity machines to make high performance computational systems by interconnecting them with a network.

LANL’s Loki and Hyglac - see *http://loki-www.lanl.gov*

INRIA’s PopC (Pile of PCs)

Internet 2 - *http://www.internet2.edu/*

- World class **research**
  Driven by computational physics, biology, chemistry, … and scientific visualization, virtual “experiments”, and remote control of real experiments.
- Networking R&D - focused on exploiting the capabilities of broadband networks media integration, interactivity, real time collaboration, …
- Improve **production** Internet services and applications for all members of the academic community, both nationally and internationally.

Purpose: support national research objectives, distance education, lifelong learning, and related efforts.

http://www.hpcc.gov/white-house/internet/background.html

Gigapops

Who will be operating them?

Where will they be?

How many will there be?

What is the aggregate throughput that they will require?

What is the maximum per port throughput?

How many ports will they need to support?

Will they support "mixing"? (mixing is used to defeat traffic analysis)

Whose hardware and software will they use? What is the required functionality?

Speed through Silicon

FPGAs used in many routers - for flexibility and to allow near hardware speed implementations of protocols.

ASICs: Vertex Networks, Inc. , MMC Networks, Inc, Galileo Technology, TI, …

Future networks

Terabit per second == 10^{12}

Readily achievable via combining multiple Gigabit per second streams using Wavelength Division Multiplexing (WDM).

Petabit per second== 10^{15}

Differentiated Services: Classes of Service, Multimedia

Constraint-based Routing (QoS Routing)

Ad Hoc Networking

Auto-configuration (Plug and Play Internet)

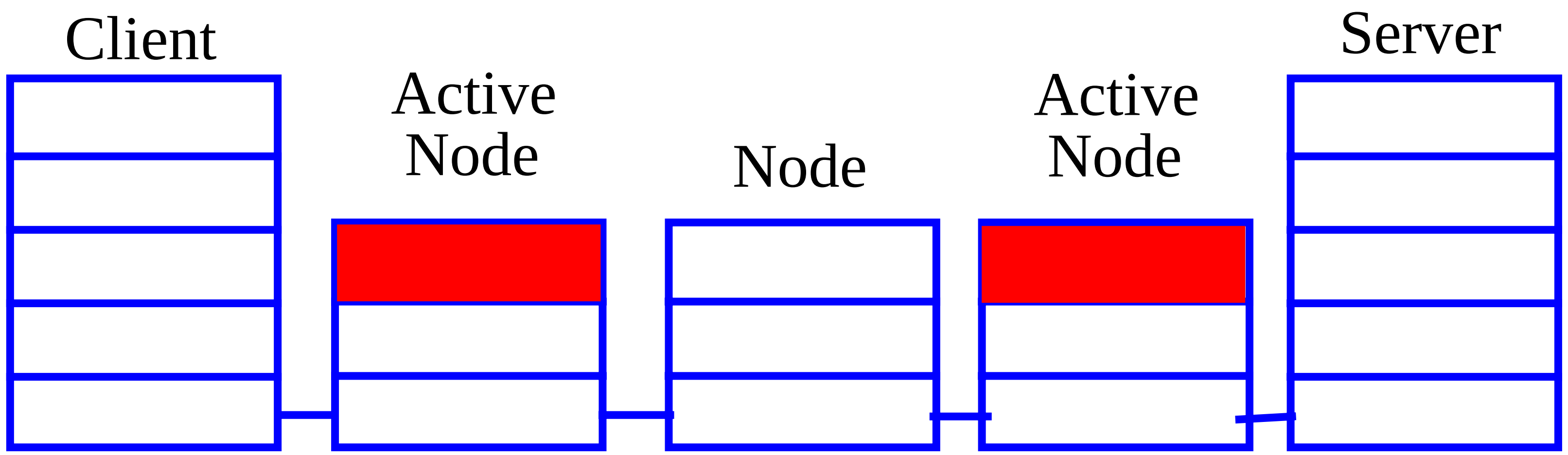
Active Networking

Smart Networking

Knowledge-based Networking

Active Networks

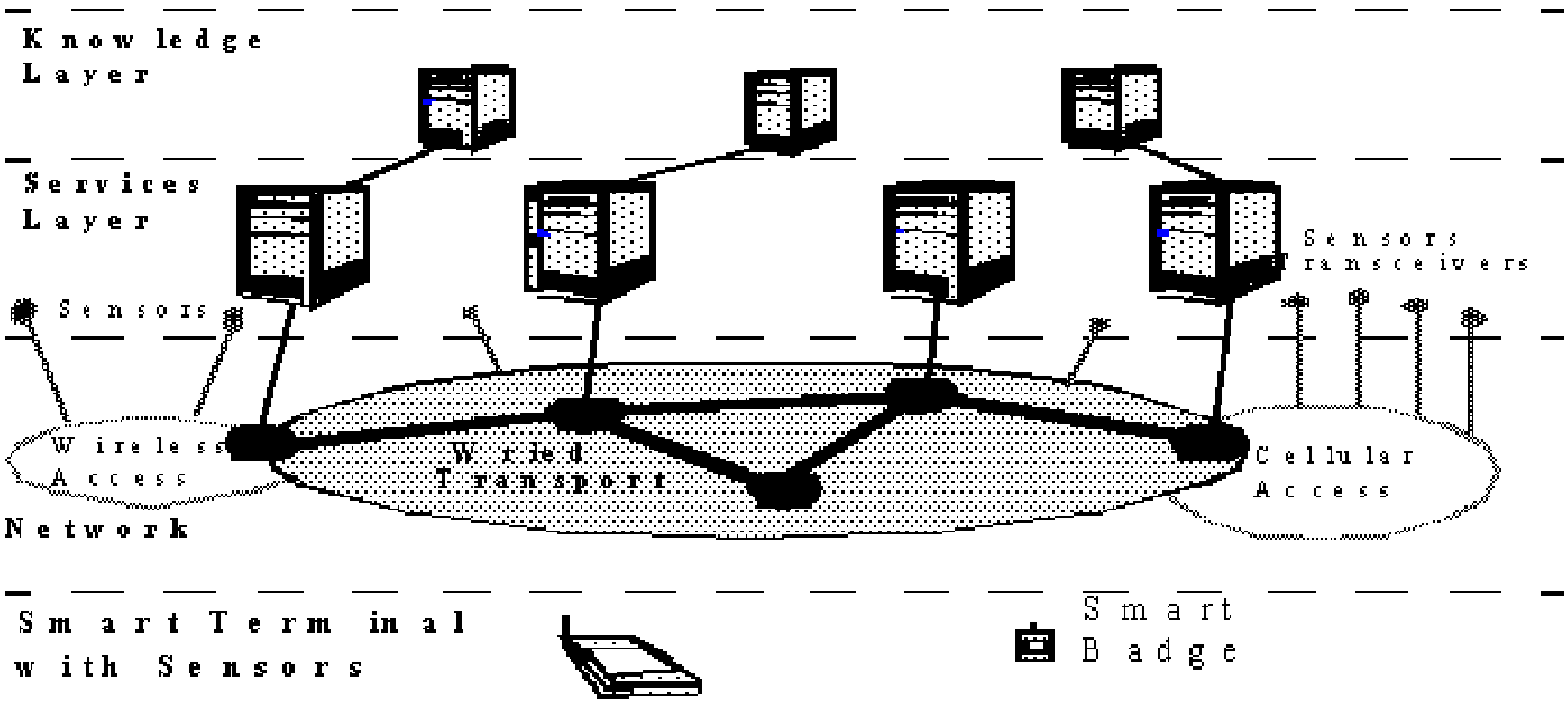
- Network nodes can perform customized computations on the messages flowing through them.
- Can change, modify the contents of the messages.
- Potentially Mobility Enabling Routing using active network concept



Smart Networks with Sensors

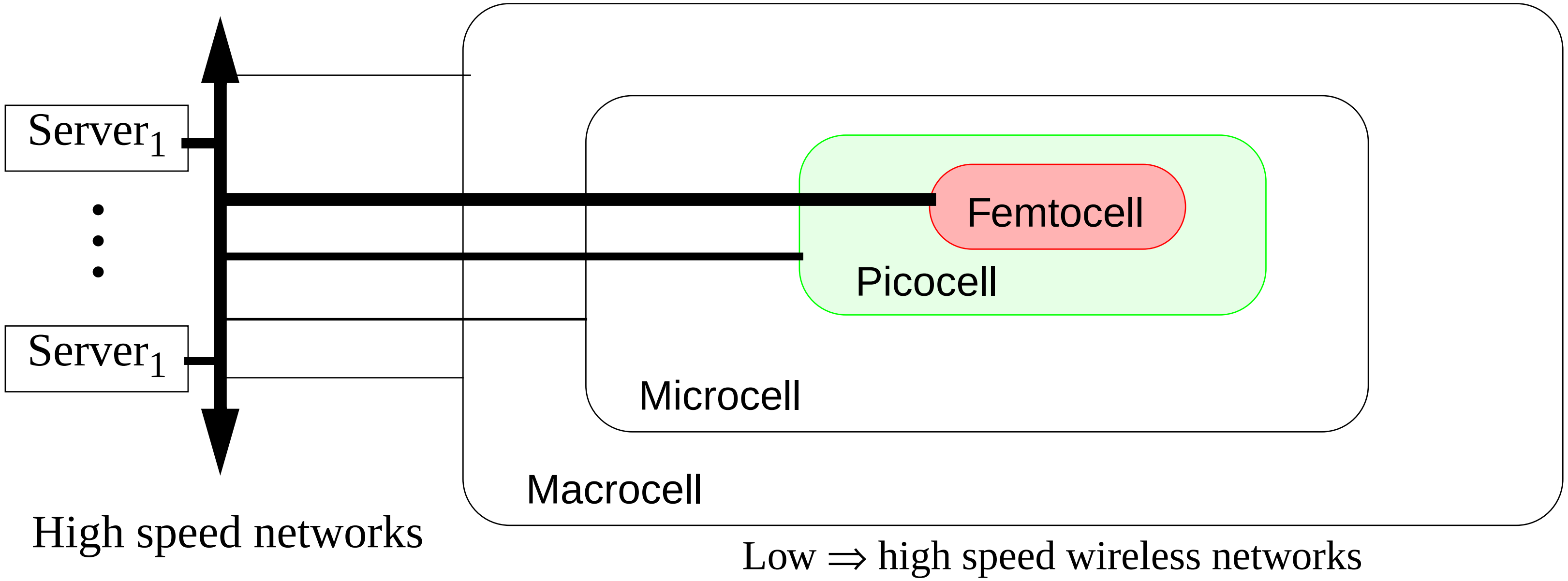
(Ren and Maguire, KTH)

- Context/situation-aware Systems
- Smart services: active + user-awareness networking
- Knowledge-based Networking

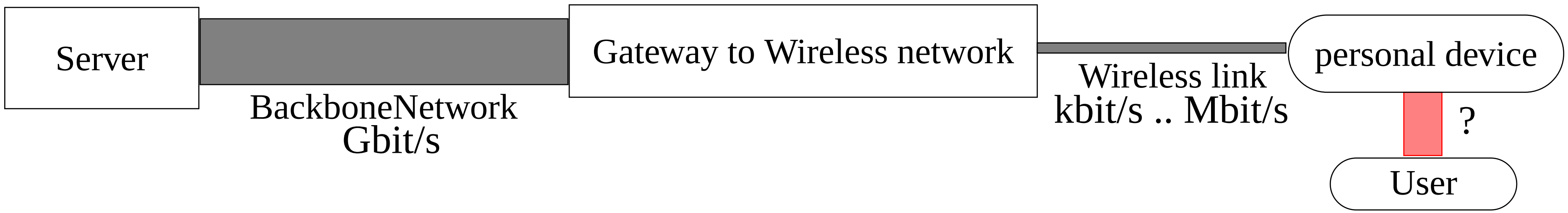


Bottlenecks

- Server and Network Bandwidth and latency



- User Bandwidth and latency



- Power and Energy ⇒ need a computational theory of O(energy)
- Imagination!

Low Earth Orbit (LEO) Satellites

When you are away from dense infrastructures there are few people and little interference, hence you might as well use LEO!

∴ UMTS is too little and too late!

- Wireless LAN already beats it in the local area
- LEO will soon beat it in the wider areas which are less populated

⇒ UMTS has no future

(it is just one more bad telecom idea, like ATM and fixed circuit-switched telephony)

⇒ National governments will be largely irrelevant

- wireless LANs use unlicensed spectrum
- LEO licenses are assigned

Near Future systems

Personal Portal

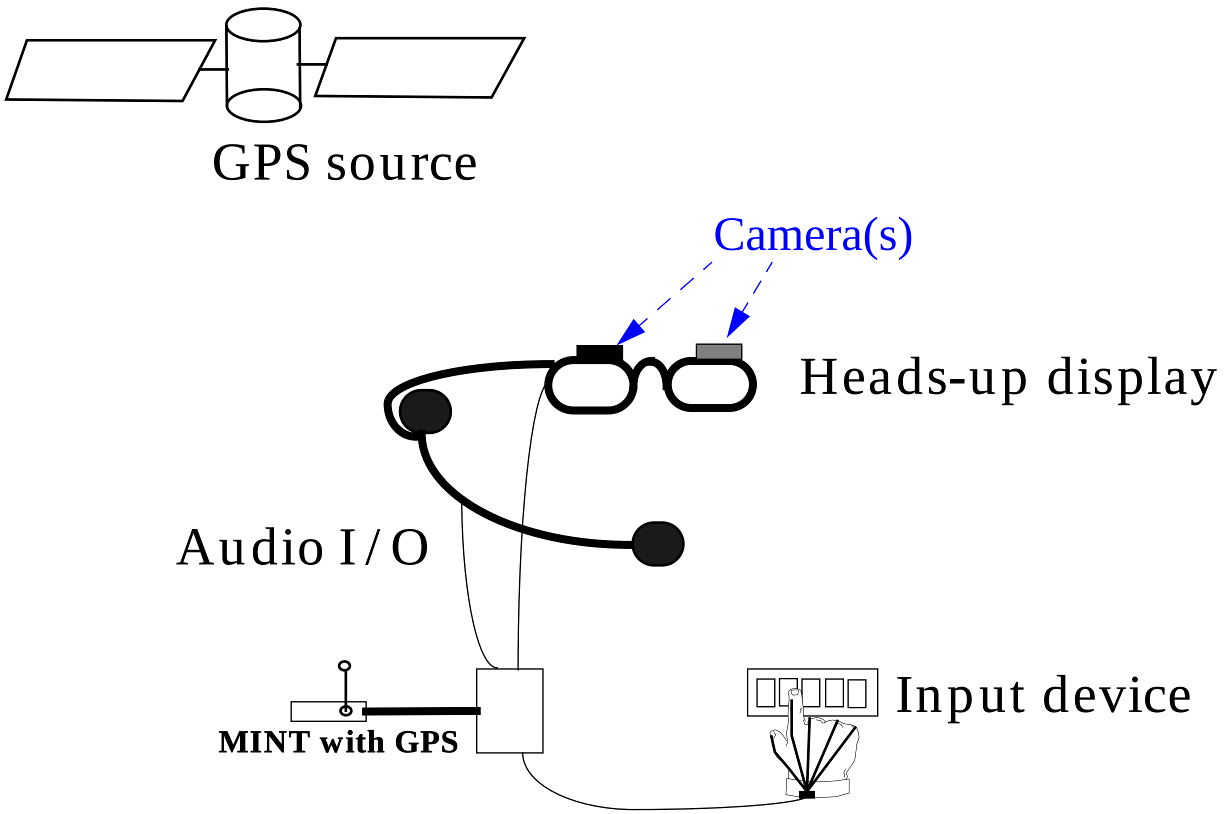


Figure 85: Vision-2, 2000 - high level of integration

Evolution of new varieties of networks

Already we have: WANs (Wide Area), MANs (Metropolitan Area), LANs (Local Area Networks)

VANs Vehicle Area Networks

Very local networks

DANs Desk Area Networks

The computer/printer/telephone/… will all be part of a very local area network on your desk.

- wireless links ⇒ No longer will you have to plug your printer into your computer (PDA/…) into your computer
- active badges⇒ No longer will you have to sign in/out of areas, write down peoples names at meetings, … the system can provide this data based on the active badges

Olivetti and Xerox are exploring “Teleporting” your windows environment to the workstation nearest you, on command, if there are multiple choices probe each one (currently a “beep” is emitted to tell the user which).

BANs Body Area Networks

Users will be carrying multiple devices which wish to communicate:

- thus there will be a need for a network between these devices which you carry around; and
- personal devices will wish to interact with fixed devices (such as Bankomat machines, vehicle control systems, diagnostic consoles (for a “mechanic” or repairman), …) and other peripherals.

Bluetooth

- Originally designed for device to device communication.
- Also provide a set of networking establishment functions.
- IP should be able to run over Bluetooth transparently.
- This can be used for:
  - Personal Area Network (PAN), Desk Area Network (DAN), AdHoc networking, Robots, Sensor networking, Games, etc.

More info: *http://www.bluetooth.com/*

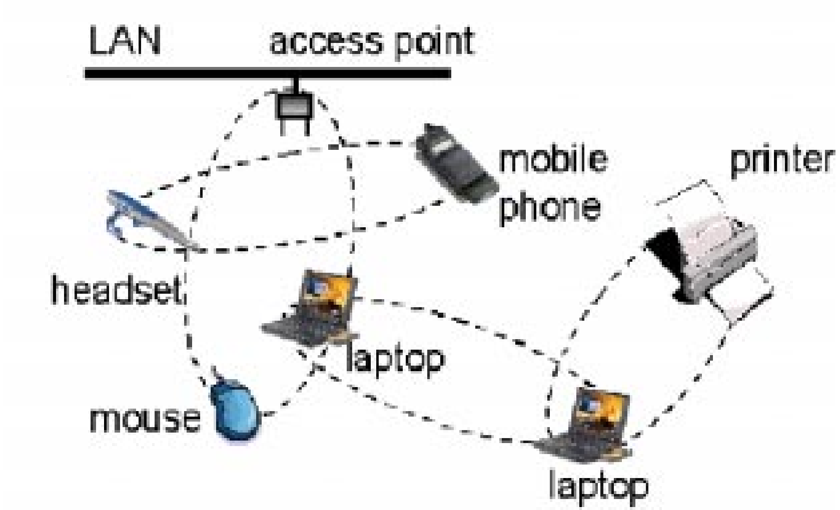


Figure from G. Liu (Internetworking course, 2001)

Situational awareness and Adaptability

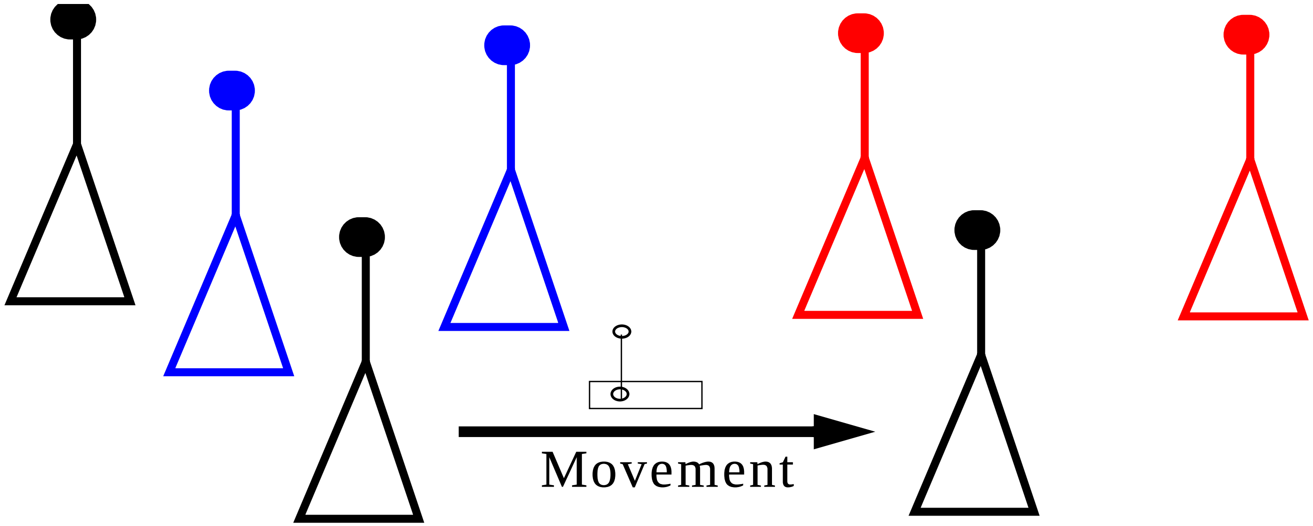


Figure 86: Where am I? What am I? Who am I?
Where am I going? When will I be there? What should I become? Who should I become?

- Location dependent services
- Predicting location to reduce latency, reduce power, hide position, …
- Adapting the radio to the available mode(s), purposely changing mode, …
- Reconfigure the electronics to adapt, for upgrades, for fault tolerance, …; Reconfiguration vs. powering up and down fixed modules (what are the “right” modules, what is the “right” means of interconnect, what is the “right” packaging/connectors/…, needed speed of adaptation)
- “right” level of independence; spectrum from Highly Independent ⇒ Very Dumb

Multiple vs. Reconfigurable Radios

Multiple types of basestations due to multiple types of networks:

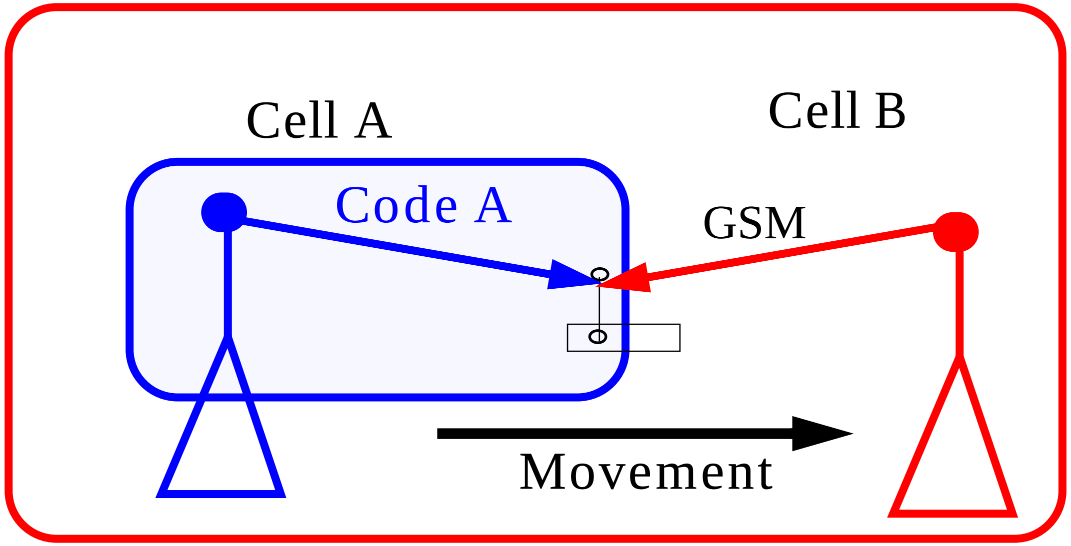


Figure 87: Two different types of networks

Radio may need to:

- have the ability to be reprogrammed to become a new radio
  - See for instance the basestations of Steinbrecher Corp. (Burlington, Mass, U.S.A.) Mini-Cell which implement a base station in a briefcase for US$100K.
    {The basestation is reprogrammed (via DSP) to handle different radios.}
  - a mix of predefined modules with some portions programmable and programmable inter-connects
- be multiple radios - with the non-used radio powered up/down as necessary;
  {There is a multiple personality radio project in the U.S. (DARPA), Motorola is one of the partners.}

Location Dependent service(s)

How do I know where I am?

- Outdoors: GPS or from the network operators knowledge [resolution: 100m to sub-centimeter]
- Indoor: IR and RF beacons, triangulation, knowing what you can **see** or **hear**

What can I do with this knowledge?

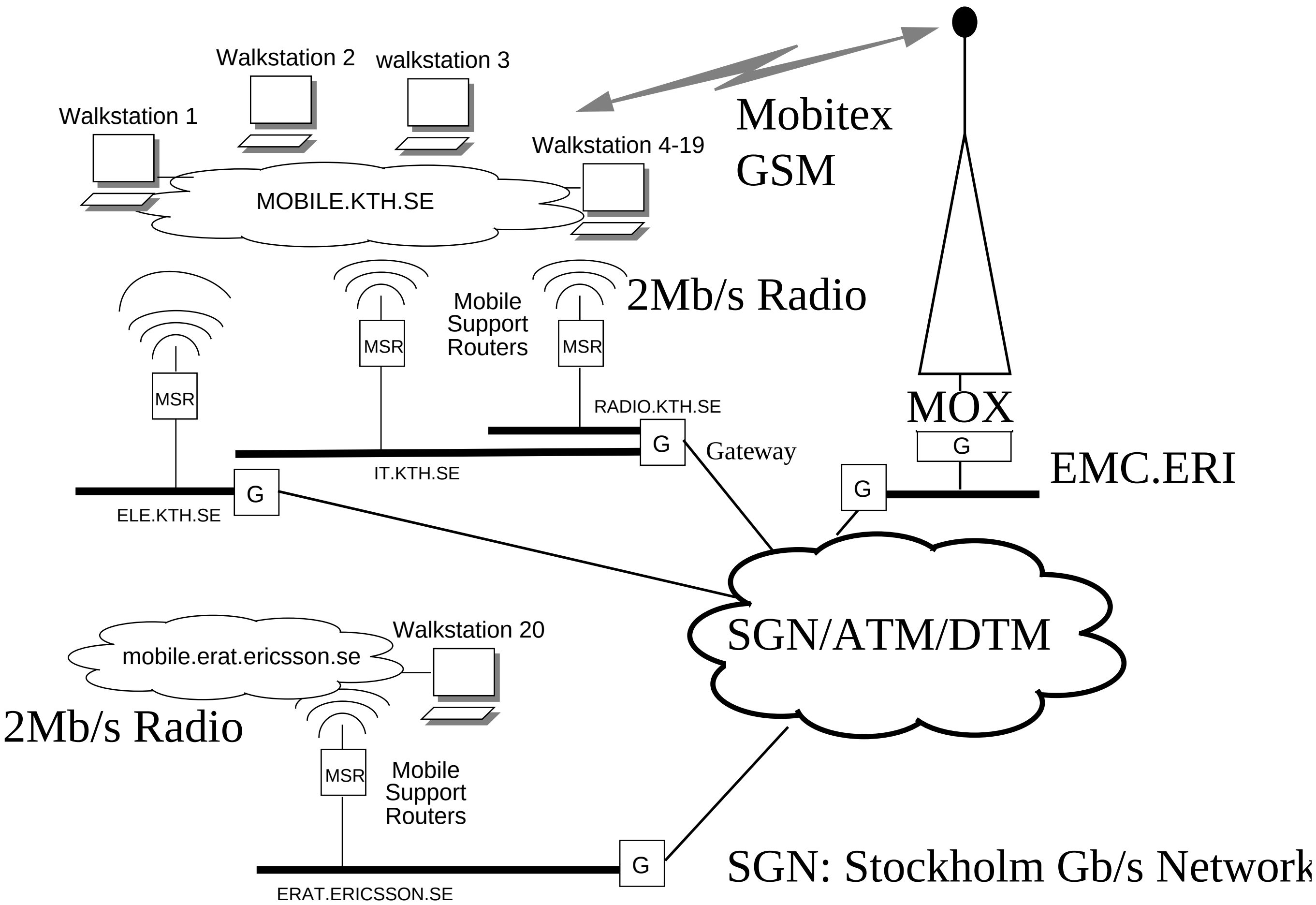
KTH students built a JAVA Applet which gets data from GPS unit and dynamically displays a list of the information available - as a function of where you are:

- ♦ if near bus, subway, train stop - you get transit information - potentially with real-time schedule - since the system knows current location of vehicles
- ♦ list of restaurants, shops, etc. where you are and in the direction you are headed
  - ◆ the scope is based on your velocity vector - so if you move quickly it reduces detail, but increases the scope
- ♦ map information with updated position

How do I know who I'm with or what I'm near?

- Olivetti, Xerox, and MIT - using IR emitters as "ID" tags
  - ♦ Olivetti put them on people, equipment, …
  - ♦ Xerox put them on electronic notepads, rooms, …
  - ♦ MIT Media Lab is putting them on people + lots of inanimate objects (clock, fish tank, …)

Location Dependent Services



To exploit the characteristics of mobility there must be:

- operating system and application level support for mobility, and
- knowledge of where the mobile is and perhaps prediction of where it is going to be.

Mobile API

Yuejin “George” Liu at Ericsson’s was involved in the OnTheMove project which developed a Mobile Applications Programming Interface (API) to address these issues

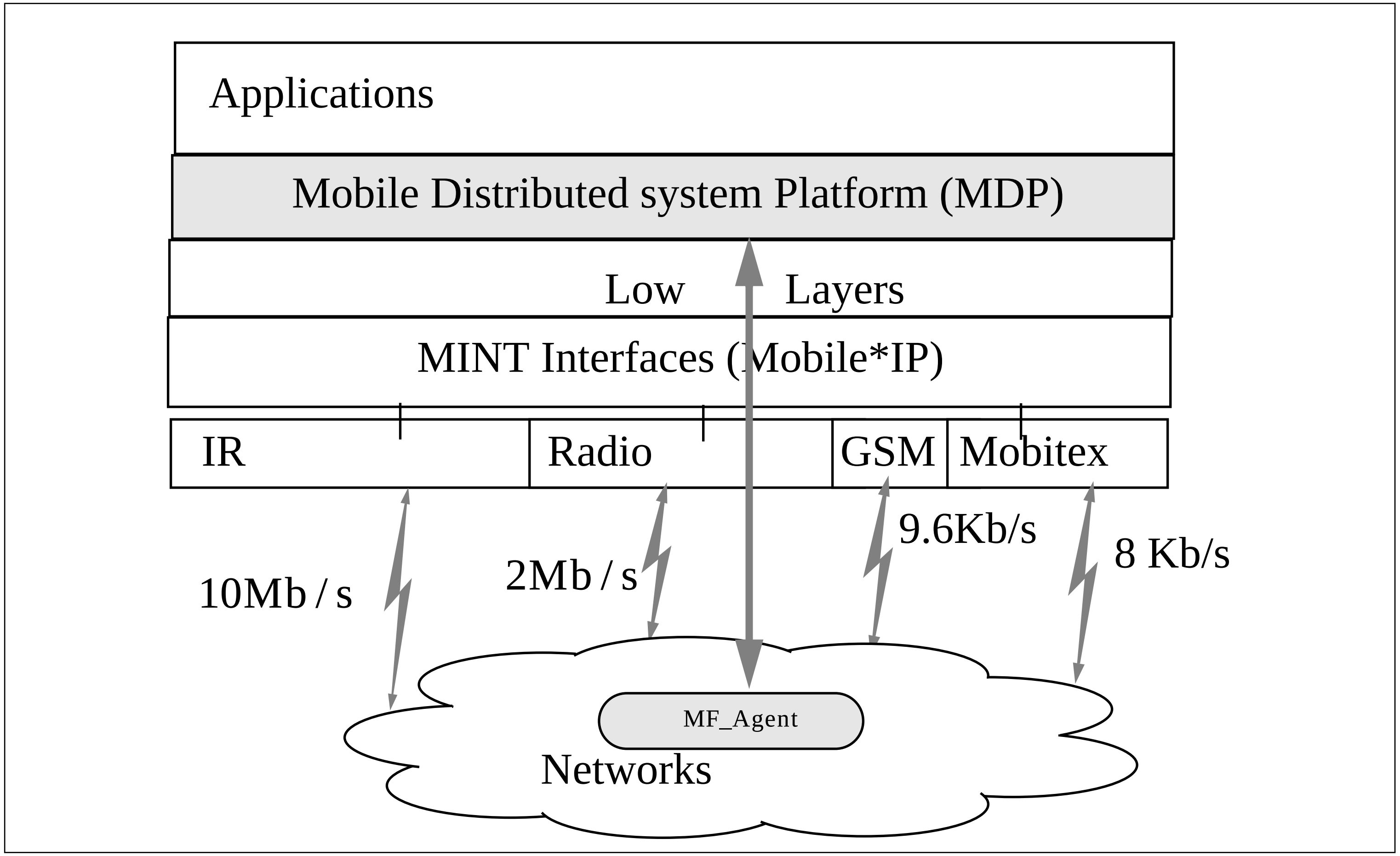


FIGURE 88. A Mobile Distributed System Platform with Mobile Floating Agent Supports Mobile Multimedia Applications

Human centered

- Computer - human interaction is currently focused on the computer (computer-centric)
  - Currently computers know little about their environment
    - Where are we?
    - Who is using me?
    - Is the user still there?
- Evolving Environment awareness
  - Give computers senses via sensors
    - Environment
    - User identity and presence
- Badge as a smart card replacement
    - biometric signature of the person currently using the badge
    - the badge ensures that only you can use it
- You wear your own personal user interface
  - interface can be consistent across all appliances
    - not because each appliance supports the interface, but because the user’s own interface provides consistency
- Make the human the focus of the computer’s interaction ($\Rightarrow$ human-centric)

Requirements

- Systems with which humans wish to interact:
  - traditional computers, desktop workspaces, domestic appliances, building and automotive systems, doors, elevators (lifts), environmental control, seats and mirrors, etc.
- Systems to provide sensor data:
  - location, orientation, light, heat, humidity, temperature, gas analysis, biomedical, …
- Systems to correlate the sensor information and provide it in a useful way to the computer systems:
  - Spatial and temporal sensor fusion,
  - 3D and 4D databases,
  - Machine Learning, and
  - Prediction (based on pattern extraction)
- Agents and actuators to provide intelligent control of the environment
- wireless/wired/mobile communications infrastructures to link it all together
  - must assure privacy and security

Dumb Badge, Smart Badge, and Intelligent Badge

- Dumb Badge just emits its ID periodically
- Smart Badge - [an IP device] Location and Context Aware (i.e., a sensor platform)
- Intelligent Badge - add local processing for local interaction by the user

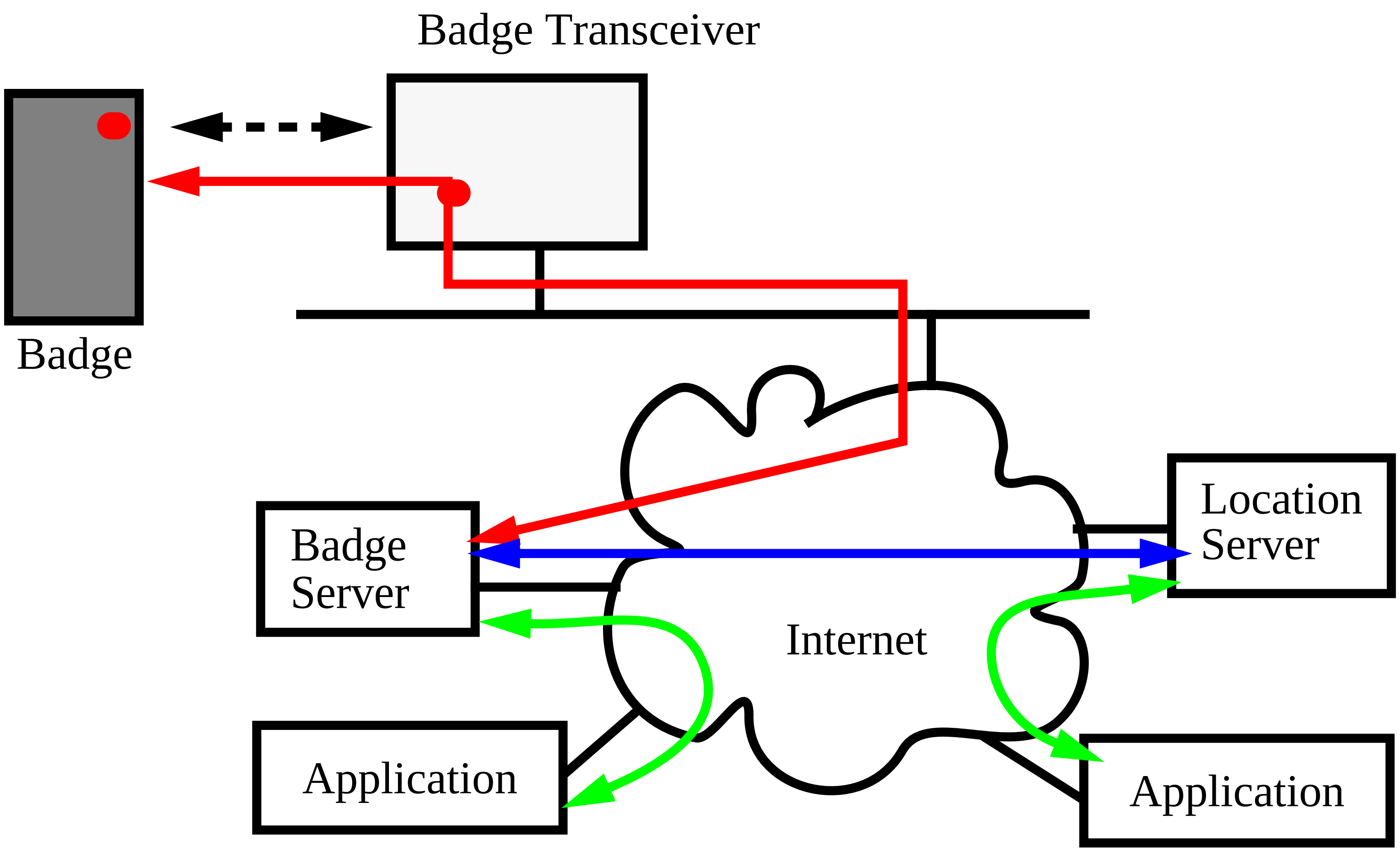
Acknowledgment:

All of the badge work is done in cooperation with:

- Dr. Mark T. Smith - Hewlett-Packard Research Laboratories, Palo Alto, California, USA
- Dr. H. W. Peter Beadle
  - ♦ Formerly: University of Wollongong, Wollongong, Australia
  - ♦ Currently: Director, Motorola Australian Research Centre, Botany, NSW, Australia

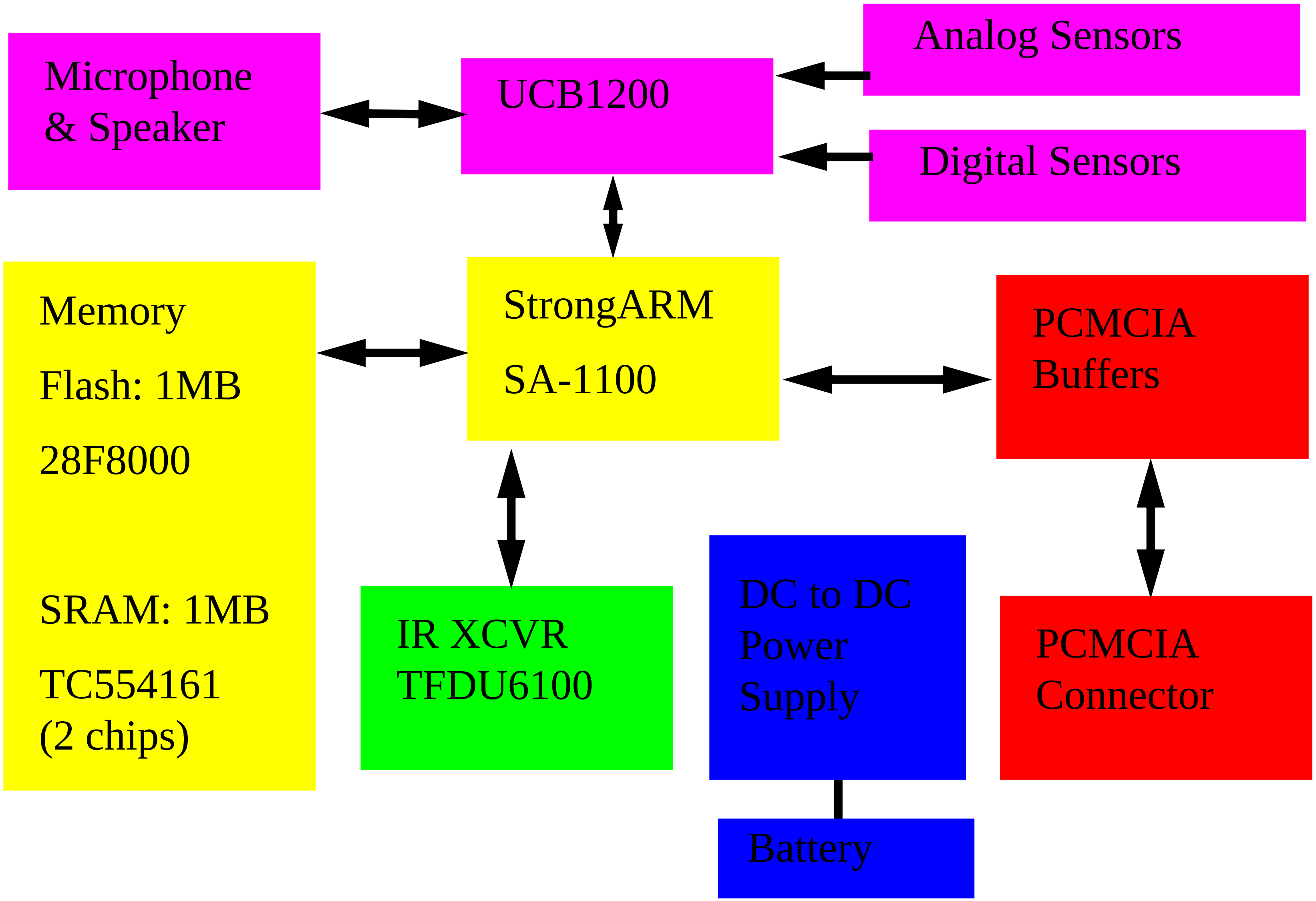
Badge Communications Model

Badges are IP devices (or should be), they communicate via network attached access points.

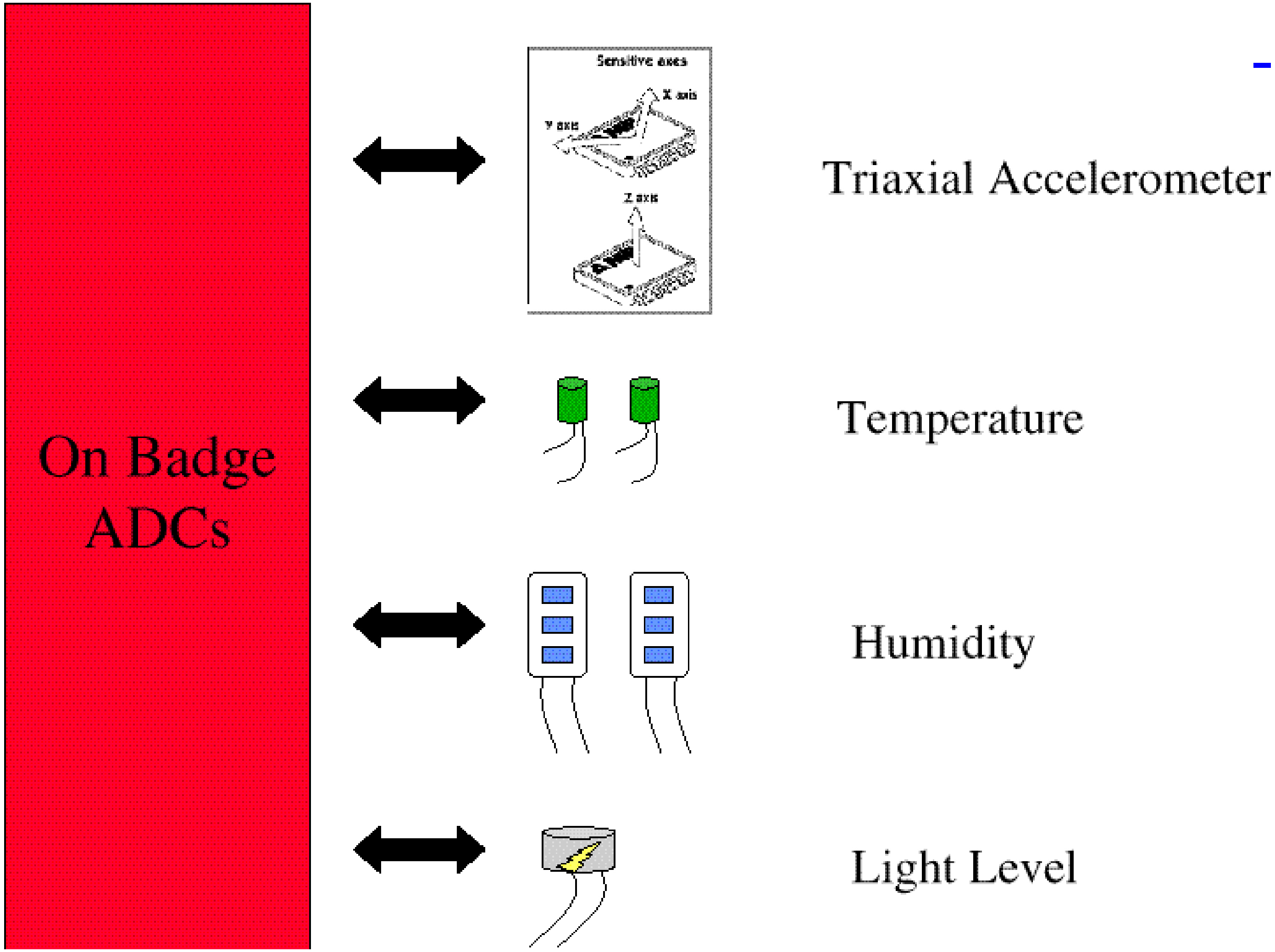


⇒ Banks as intermediaries (**if** they have **any** future role)

Smart Badge 3

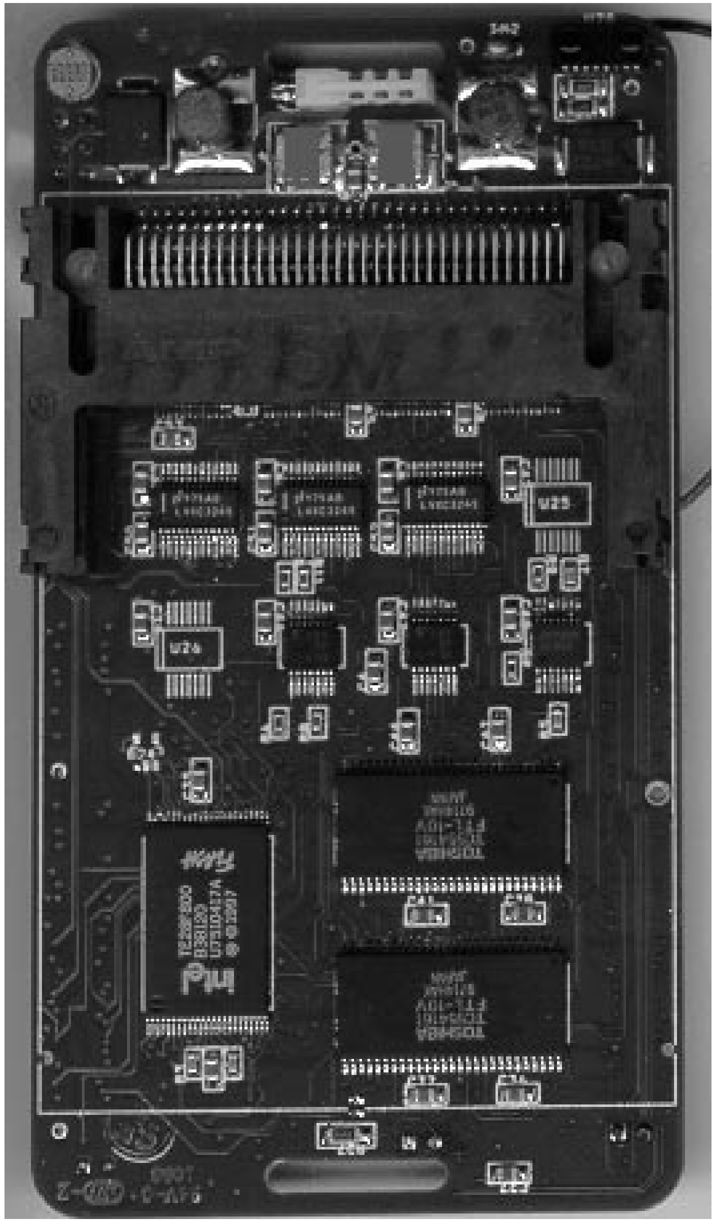


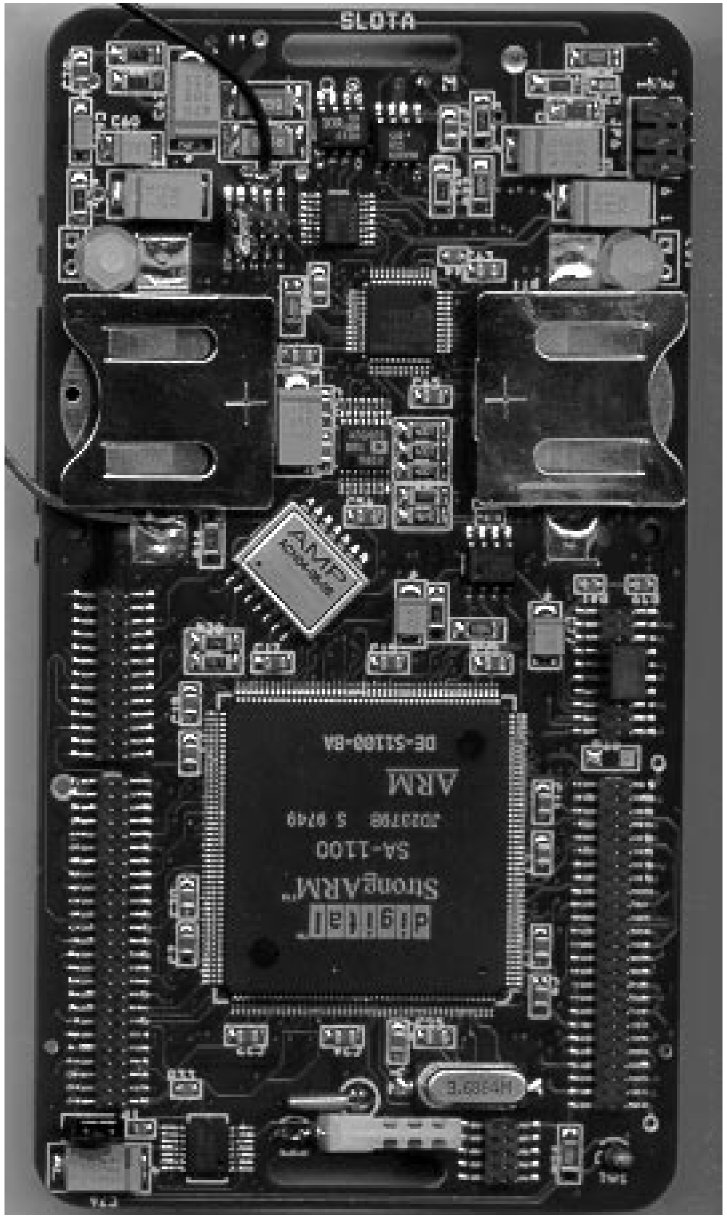
Smart Badge Sensors



Details of the 3rd version:
http://www.it.kth.se/edu/gru/Fingerinfo/telesys.finger/Mobile.VT98/badge3.html

Badge 3

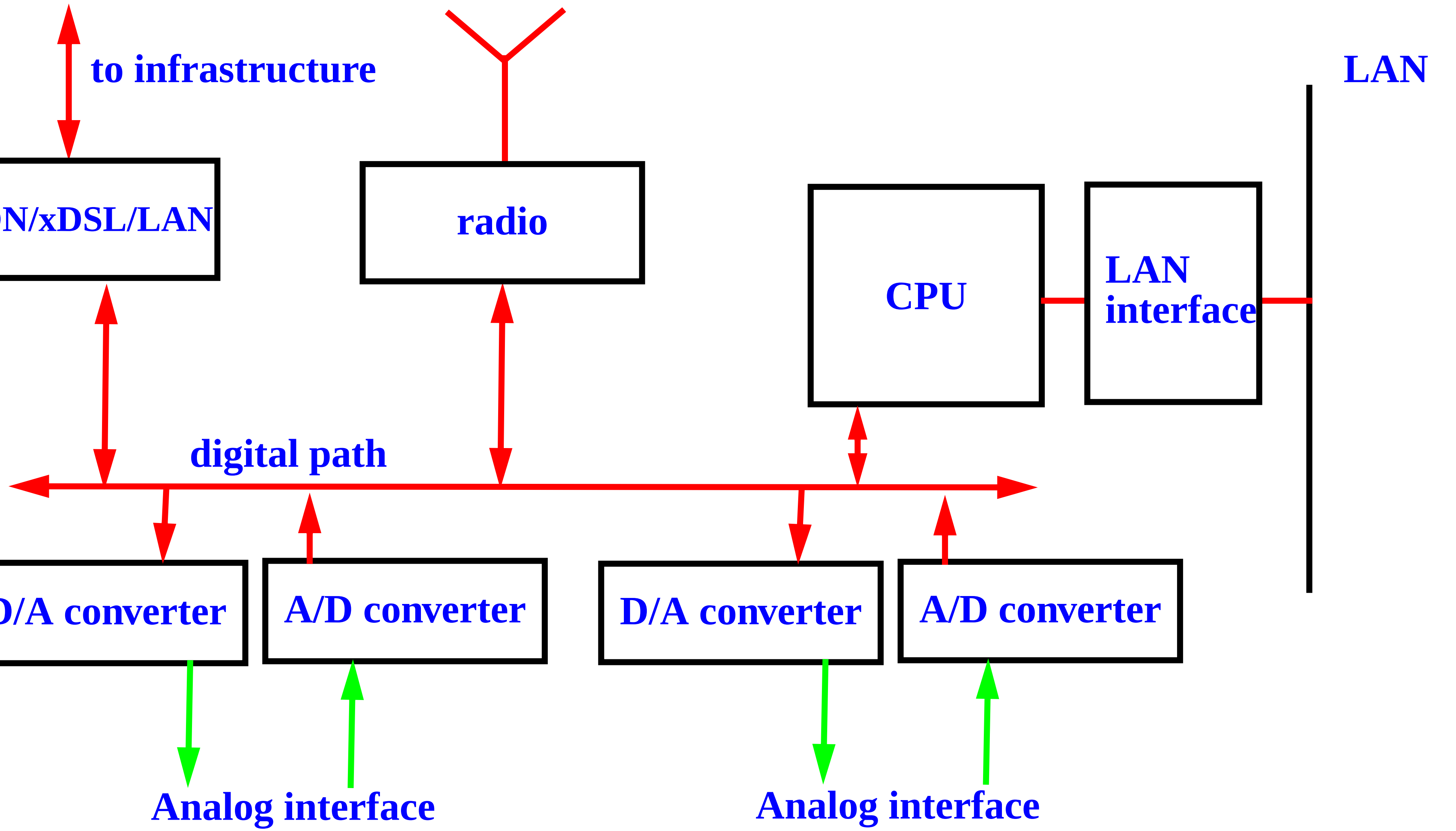




A view of the packaged badge

As shown by HP at Comdex'98, November 16-20, 1998

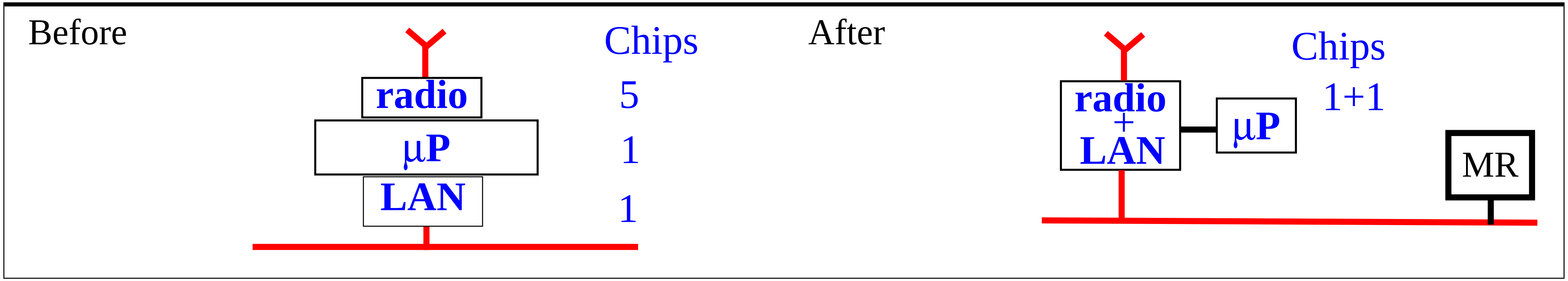
Local access point



All but the radio are current inside an Ascend Communications Pipeline 25 or 75.

MEDIA

High integration (goal of MEDIA project)

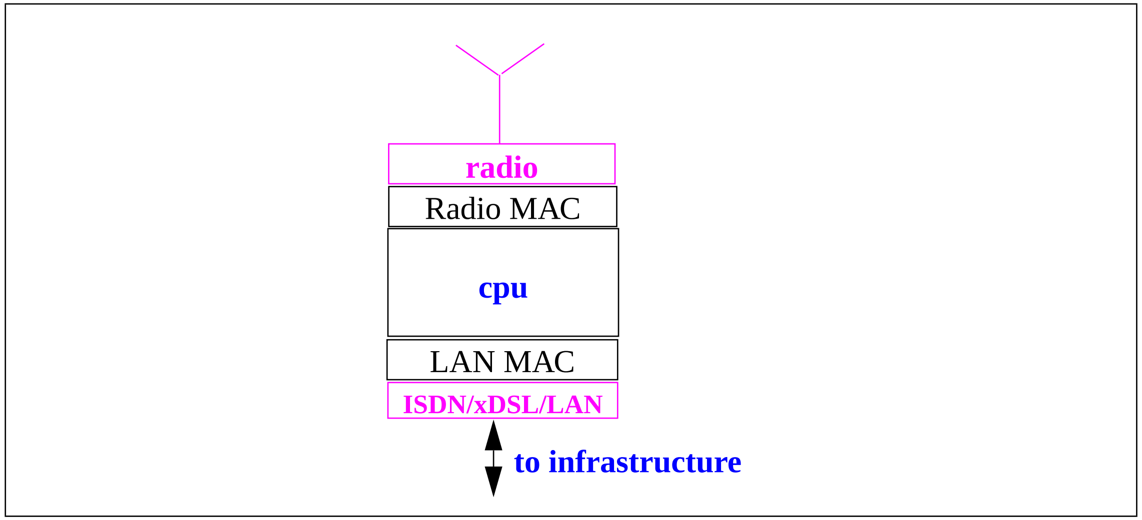


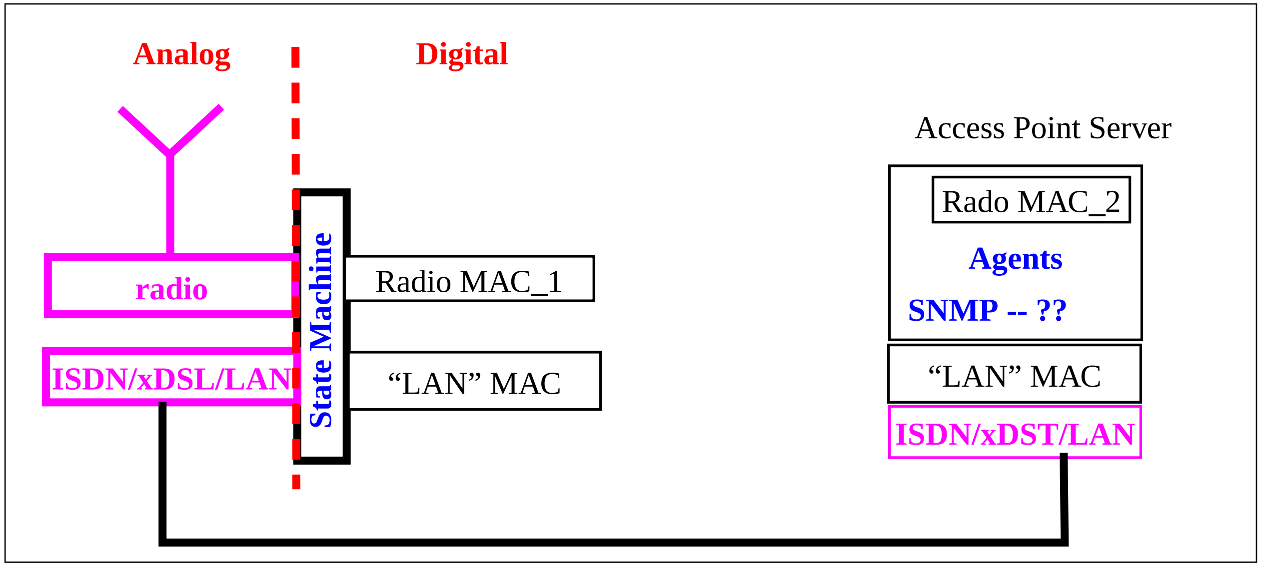
Partners:

- Kungl Tekniska Högskolan (KTH/ELE/ESDlab and KTH/IT/CCSlab)
- Tampere University of Technology (TUT)
- GMD FOKUS (GMD)
- Technische Universität Braunschweig (UBR)
- Interuniversity Microelectronics Centre (IMEC)
- Ericsson Radio Systems AB (ERA)

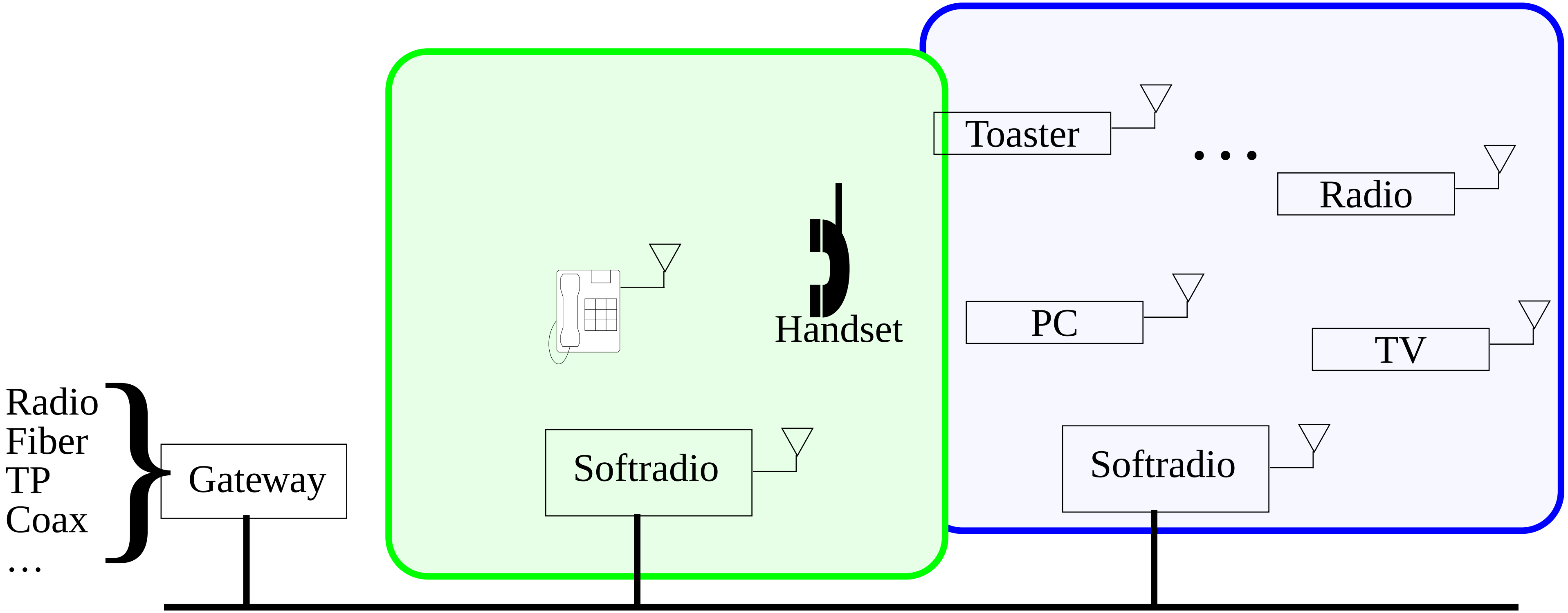
See http://www.ele.kth.se/ESD/MEDIA for more information

Split the functions between access point and access point server





Future home/office/… network accesspoints



Personal Computing and Communication (PCC)

Upper limit of bandwidth: saturate the senses: sight, sound, touch, smell, taste

$\Rightarrow$ ~1 Gbit/sec/user

Current workstations shipping with 1 Gbit/sec interfaces for LAN!

Telepresense for work is the long-term “killer” application

-- Gordon Bell and James N. Gray[1]

1. “The Revolution Yet to Happen” in Beyond Calculation: The Next Fifty Years of Computing, Eds. Denning and Metcalfe, Copernicus, 1997.

Uploading ourselves to the net

In Bob Metcalf's speech at MIT: http://web.mit.edu/alum/president/speech.html

One of great insights of this talk is that the internet is the way to immortality[1]:

> Now, for the next 50 years, the web will drive electronic commerce into the information age, ubiquitous computers will disappear into the woodwork, and we'll start uploading ourselves into the Internet to become at last immortal.
>
> -- Robert M. Metcalfe
> June 26, 1997

1. Robert M. Metcalfe, "Internet Futures", MIT Enterprise Forum, June 26, 1997.

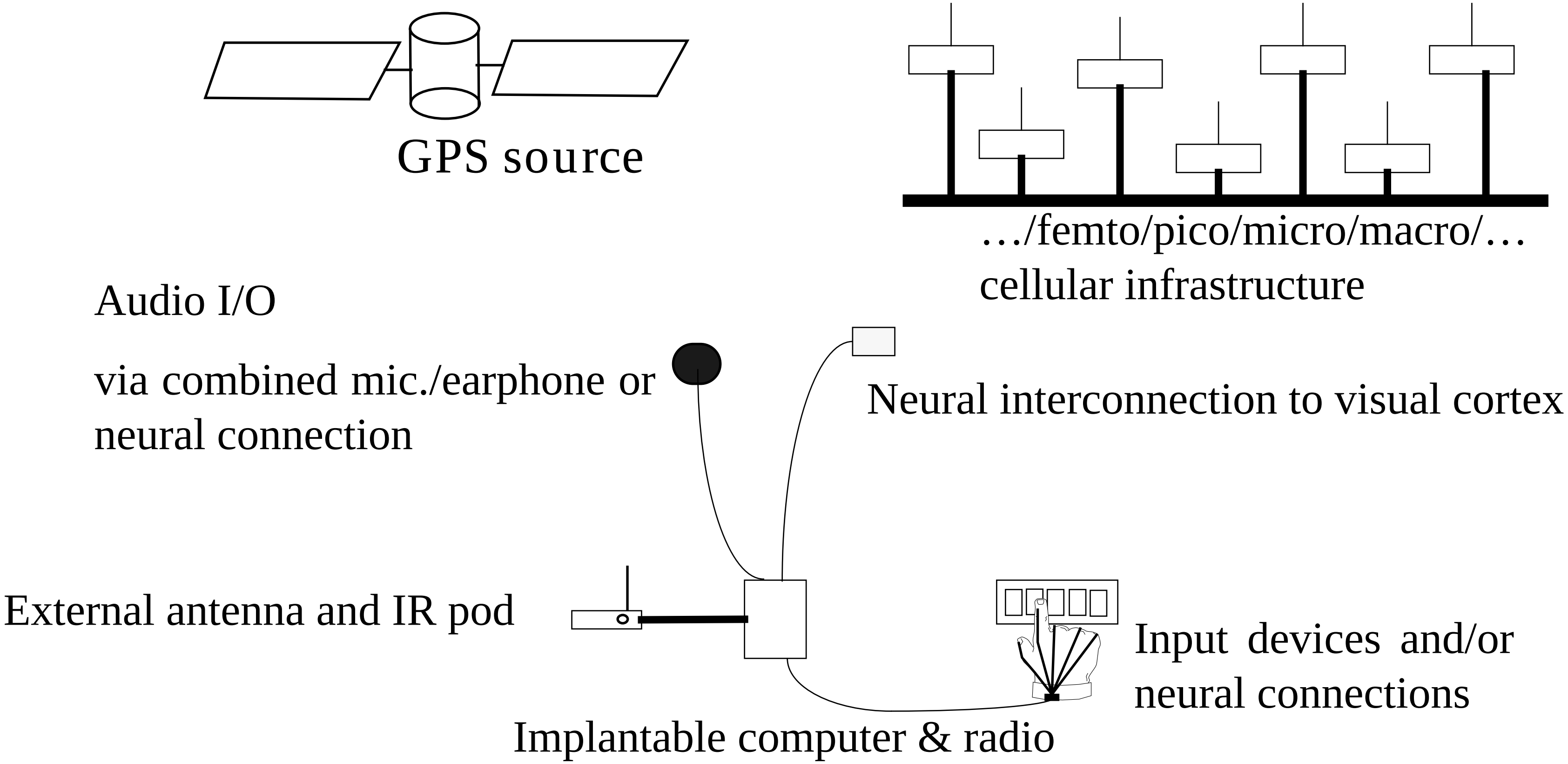


Figure 89: Vision-3, 2005-2015 - very high level of integration

Bionic Technologies, Inc.'s Intracortical Electrode Array

Acute microelectrode assembly (10x10 array, 100 active electrodes) $1,250.00

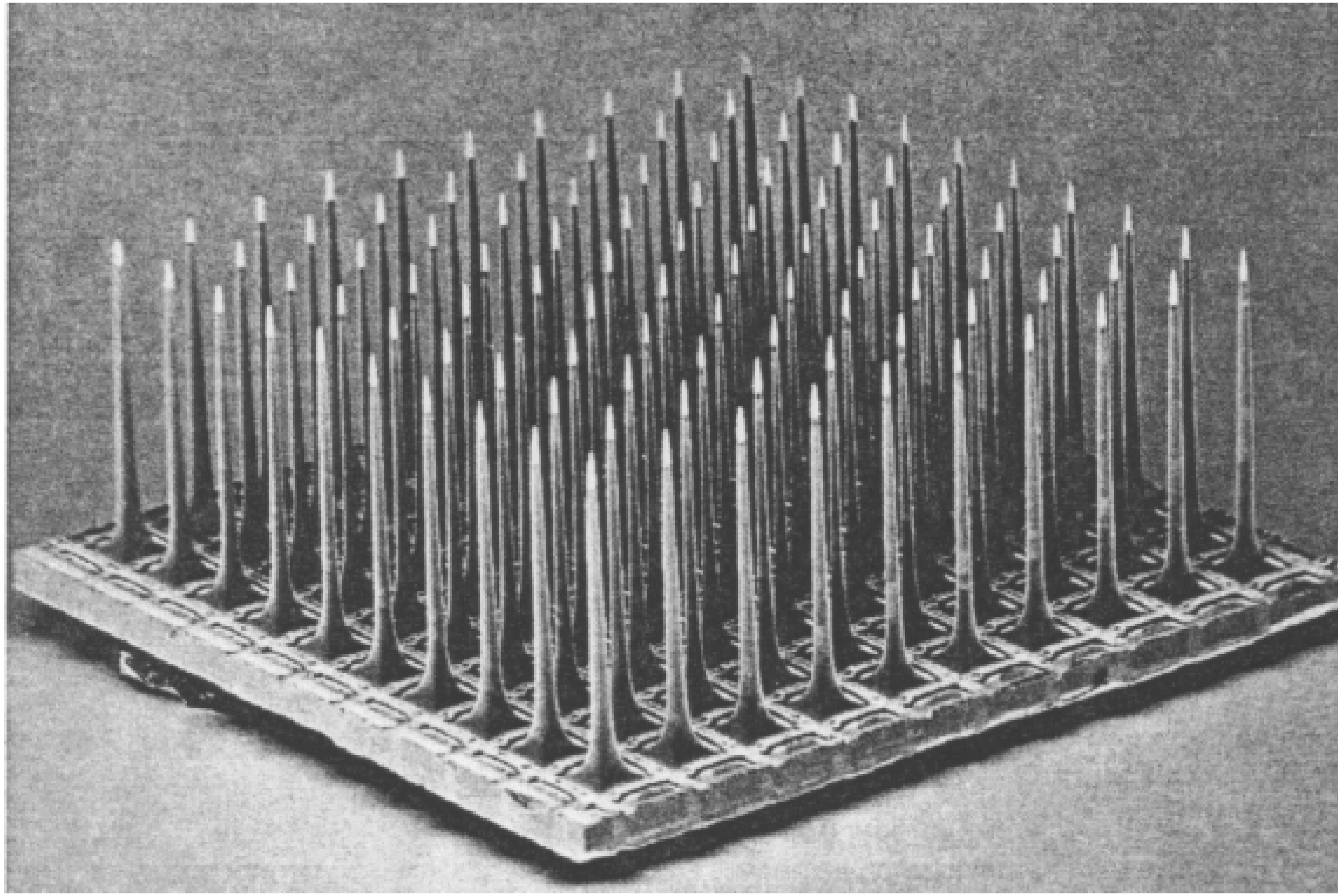


Figure 90: 10 x 10 silicon electrode array (each electrode: 1.5mm long, 0.08mm wide at base, 0.001mm tip), Built at the Univ. of Utah, by Richard A. Normann, et al.; from Scientific American, March 1994, pg. 108.

Non-metalic bi-directional neural interfaces

Neurochip: Neuron silicon circuits http://mnphys.biochem.mpg.de/ :

(a) Silicon-Neuron Junction (input to the nerve) (b) Neuron transistor (output from the nerve)

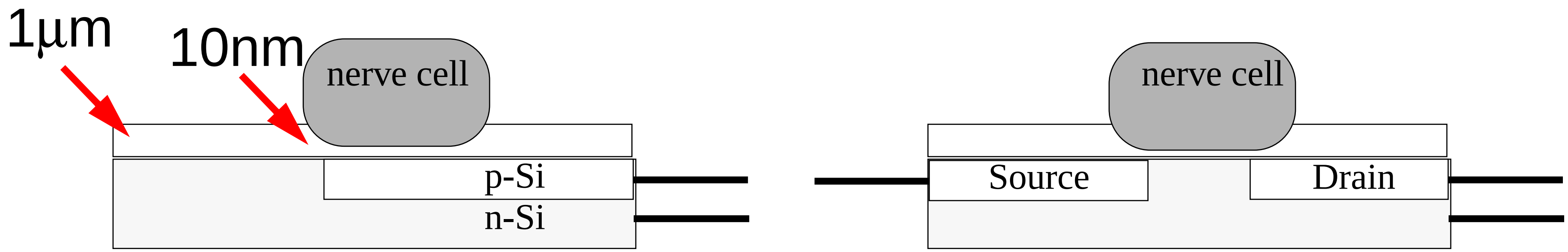


Figure 91: (a) Capacitive coupling of data into nerve and
(b) using the charge in the nerve to control a transistor's gate for getting data out of the nerve

(a) Peter Fromherz and Alfred Stett, "Silicon-Neuron Junction: Capacitive Stimulation of an Individual Neuron on a Silicon Chip" Phys.Rev.Lett. 75 (1995) 1670-1673

(b) P.Fromherz, A.Offenhäusser, T.Vetter, J.Weis, "A Neuron-Silicon Junction: A Retzius-Cell of the Leech on an Insulated-Gate Field-Effect Transistor" Science 252 (1991) 1290-1293.

What is your time line?

- What is going to be your planning horizon?
  - ♦ The new VP of a major telecom operator's research laboratory thinks 12 months is long term planning! Expectation of a senior researcher is that this VP will soon be replaced.
    What if he is not?
- What will be the depreciation time for your equipment/software/infrastructure/… ?
- How fast:
  - ♦ can you change?
  - ♦ should you change?
  - ♦ will you change?

Summary

- Telecom operators are reinventing themselves and their infrastructures
- Things to watch IPv6, IPsec, Mobile-IP, DHCP, the new domain name registries, appliances, …
- Low cost access points which exploit existing or easily installed infrastructure are key to creating a ubiquitous mobile infrastructure with effectively infinite bandwidth.
- Smart Badge is a vehicle for exploring our ideas:
  - Exploits hardware and software complexity by hiding it.
  - Explores allowing devices and services to use each other in an extemporaneous way.
  - Enables a large number of location and environment aware applications, most of which are service consuming.
  - Keep you eyes open for the increasing numbers of senors which will be on the network.
  - Service is where the money is!
- Personal Communication and Computation in the early 21st century: “Just Wear IT!”
- Coming in 20-30 years: “Just implant IT!”
- Remember: The internet will be what you make it.

Further Reading

General: *http://www.ietf.org/*

Mobile IP: *http://www.ietf.org/html.charters/mobileip-charter.html*

Thanks

Best wishes on your written assignments (or projects) and on the exam.