Evolution of the Internet Core and Edge
IP Wireless Networking

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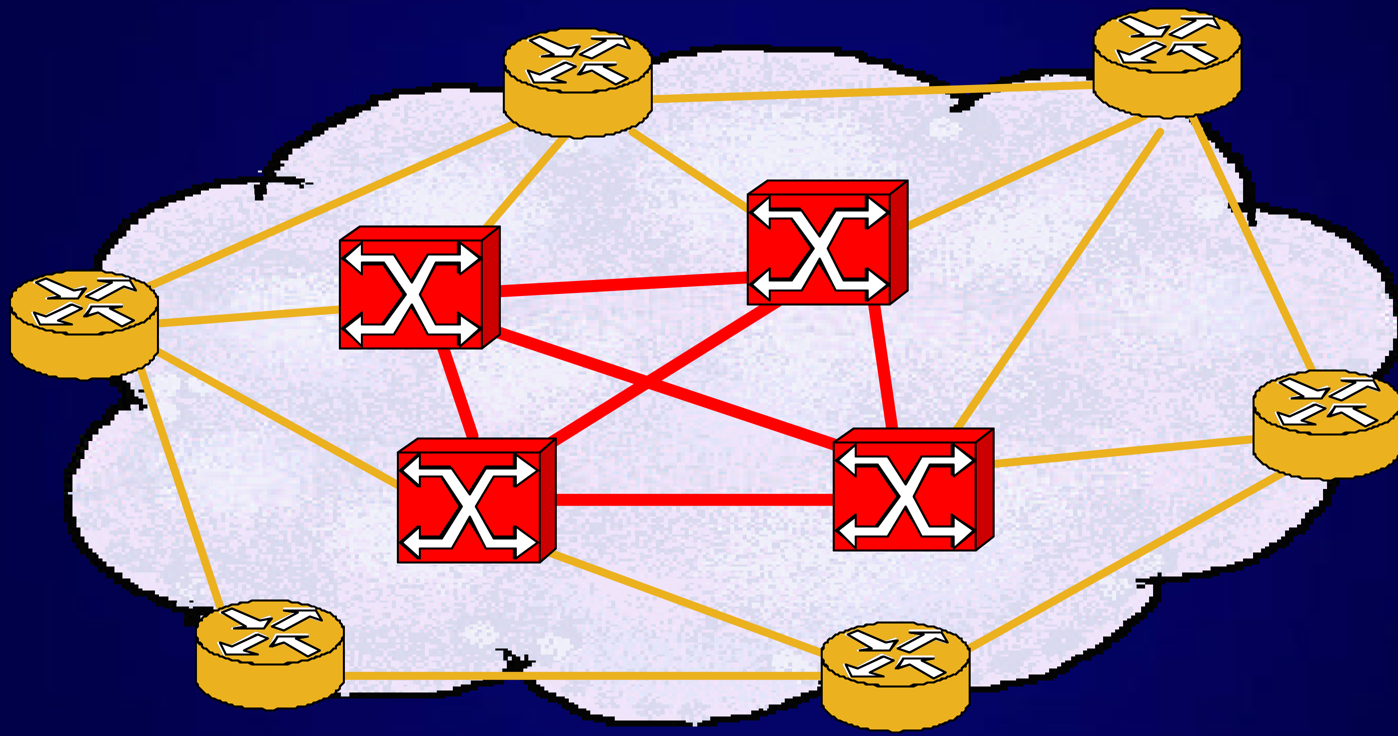
Discussion

- Internet and Current Wireline IP Evolution
- Wireless Evolution
- IPv6 Evolution
- Mobile IP Evolution
- The Future: Wireless and Wireline Integrated

Internet and Current Wireline IP Evolution

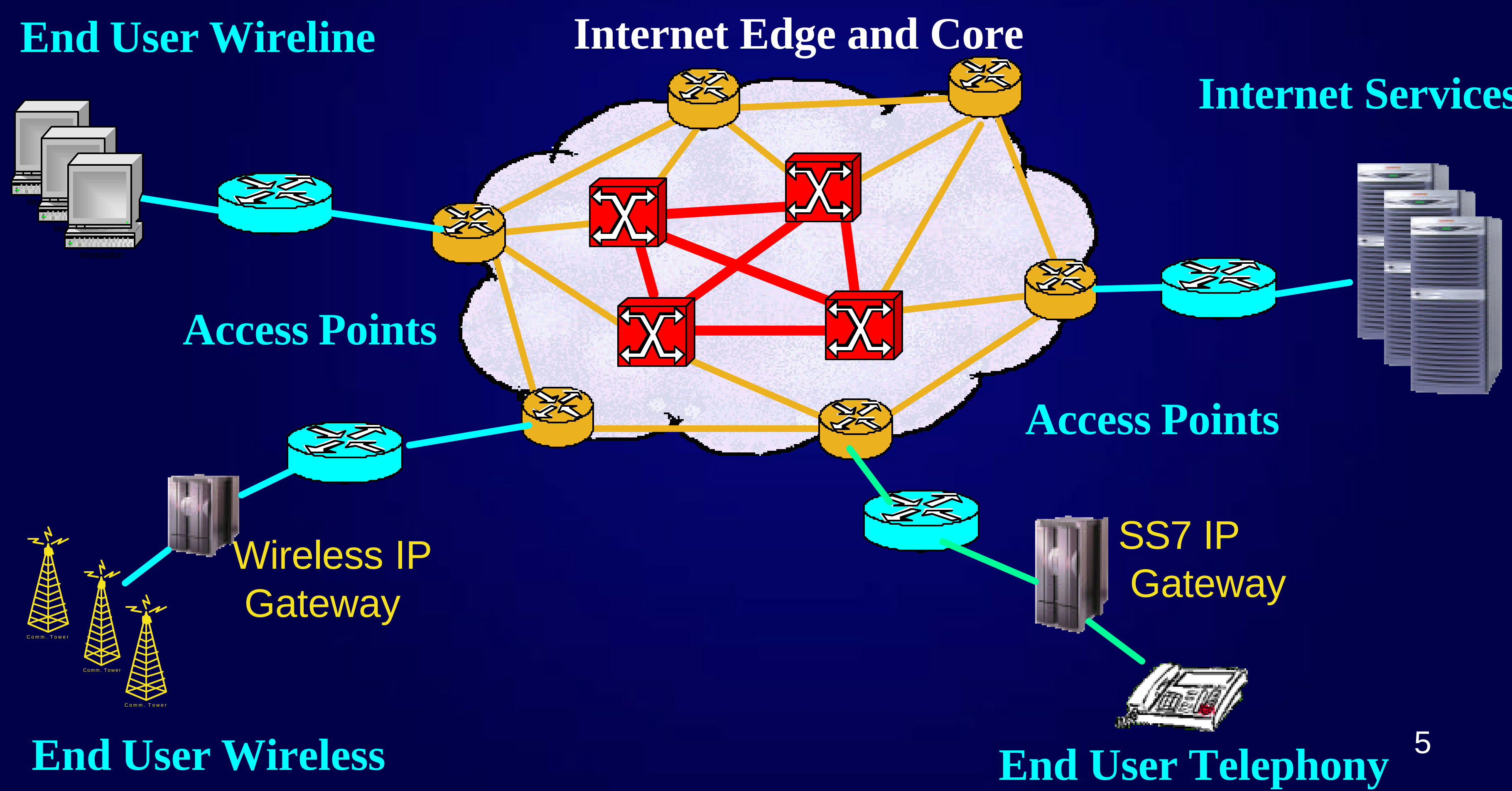
Internet Core and Edge



Edge Communications

Core Communications

Internet Access Point



Internet Characterization Today

- Virtual Private Networks
  - Tunnels
  - Private Addresses
  - Secure at Edge or Access Only
- Network Address Translation (NAT) Required
- End-2-End Model is Lost
- Try getting a Globally Routable IPv4 Address in Europe or Asia; or a set of them for your business !!!
- These are not optimal conditions for the evolution of the Internet

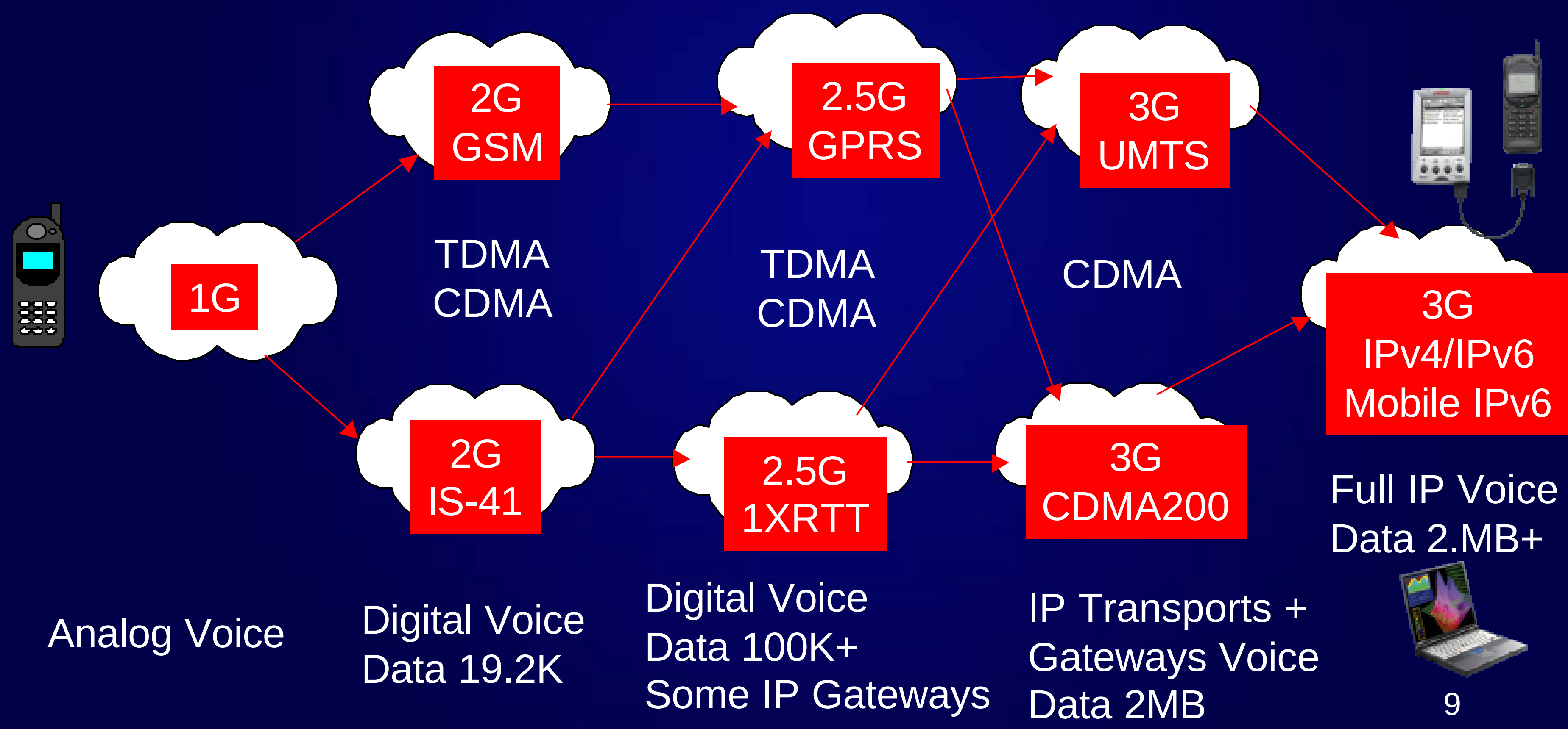
Internet engineers are working on it !!!

- The Next Generation Internet Protocol is IPv6 and will restore the End-2-End model of the Internet
- 2.5G and 3G Wireless requires the End-2-End model as it moves its use model to the Internet.
- Mobile IP computing will revolutionize the Internet as the WEB did in the 90's.
- So lets discuss how this will happen!!!

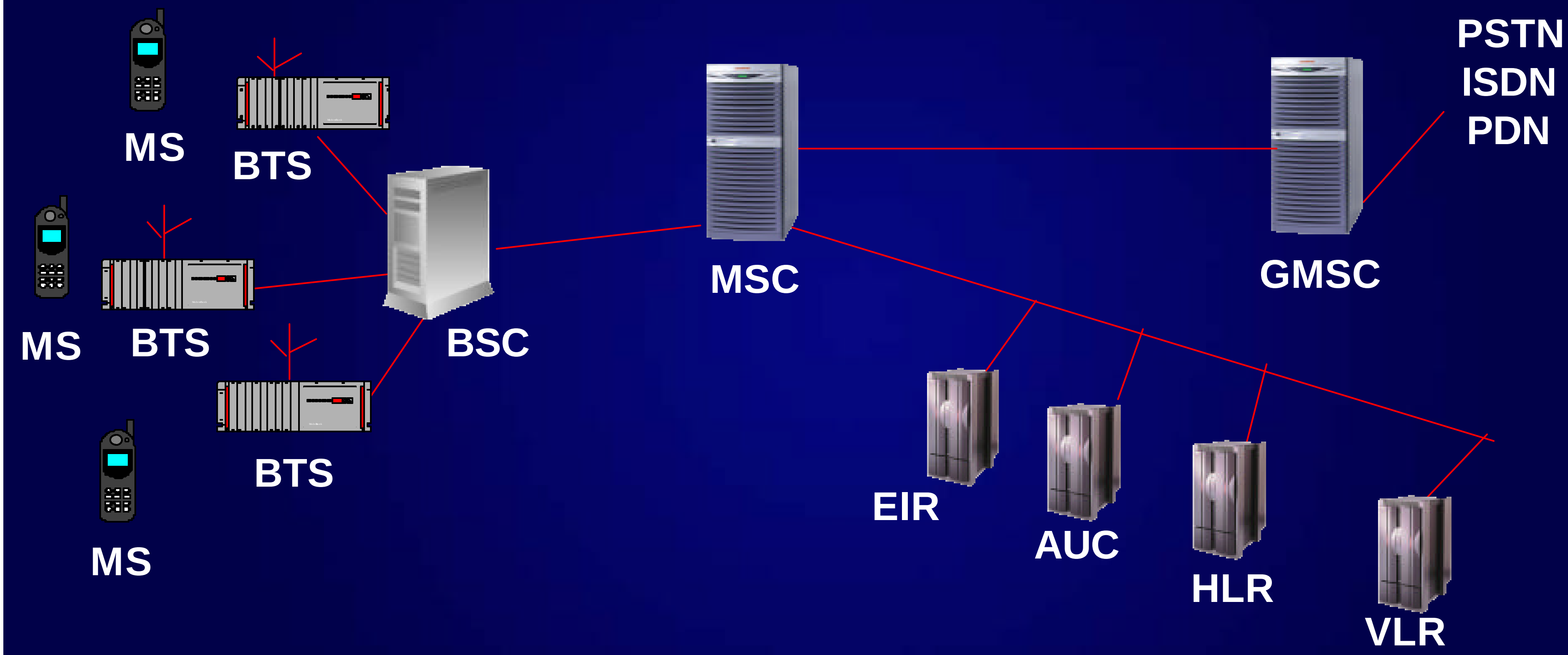
Wireless Evolution

Wireless Evolutionary Stages

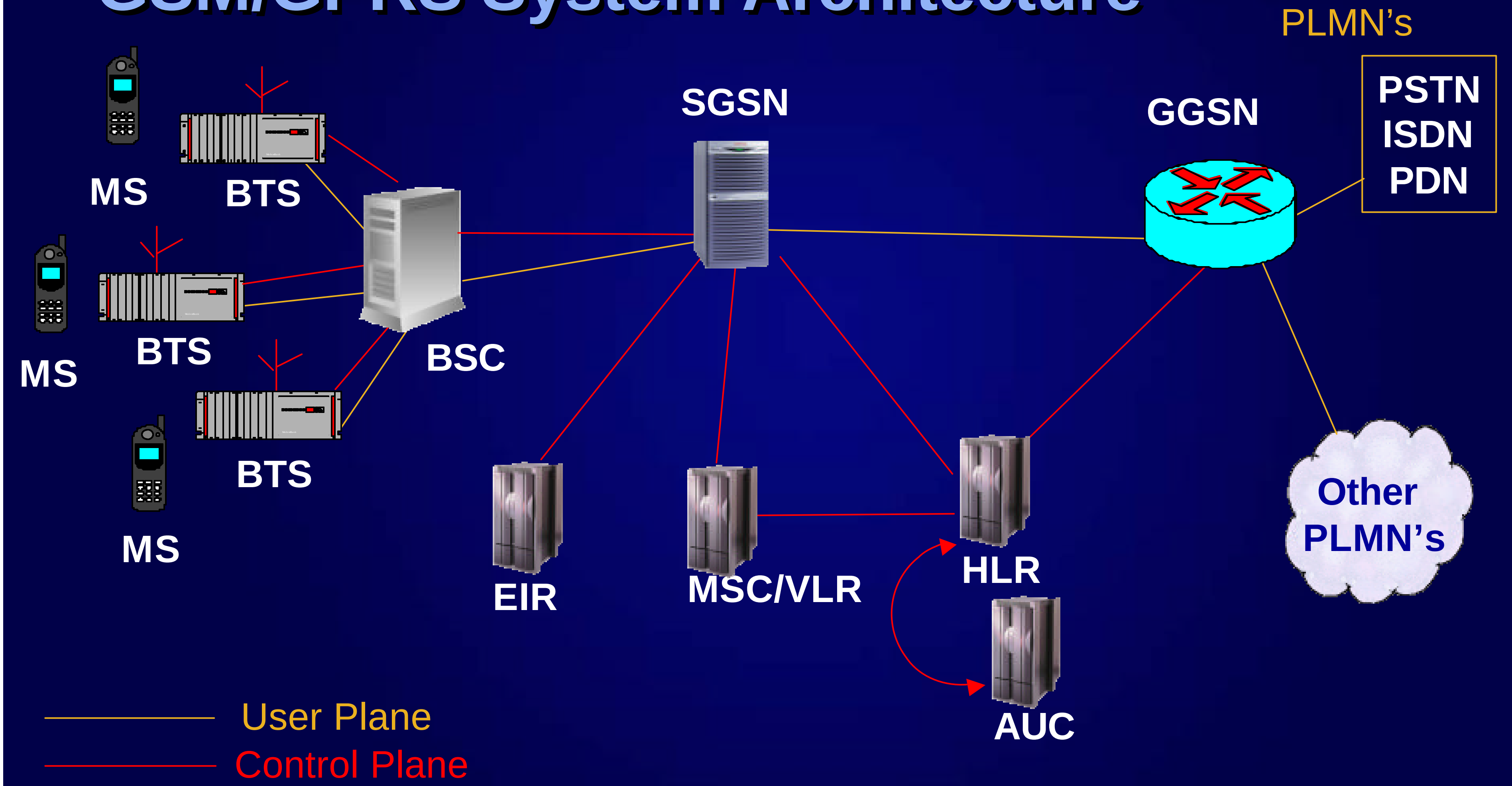
Timeline ------------------------------- Today ----------- 2002-2003 ----------2003+



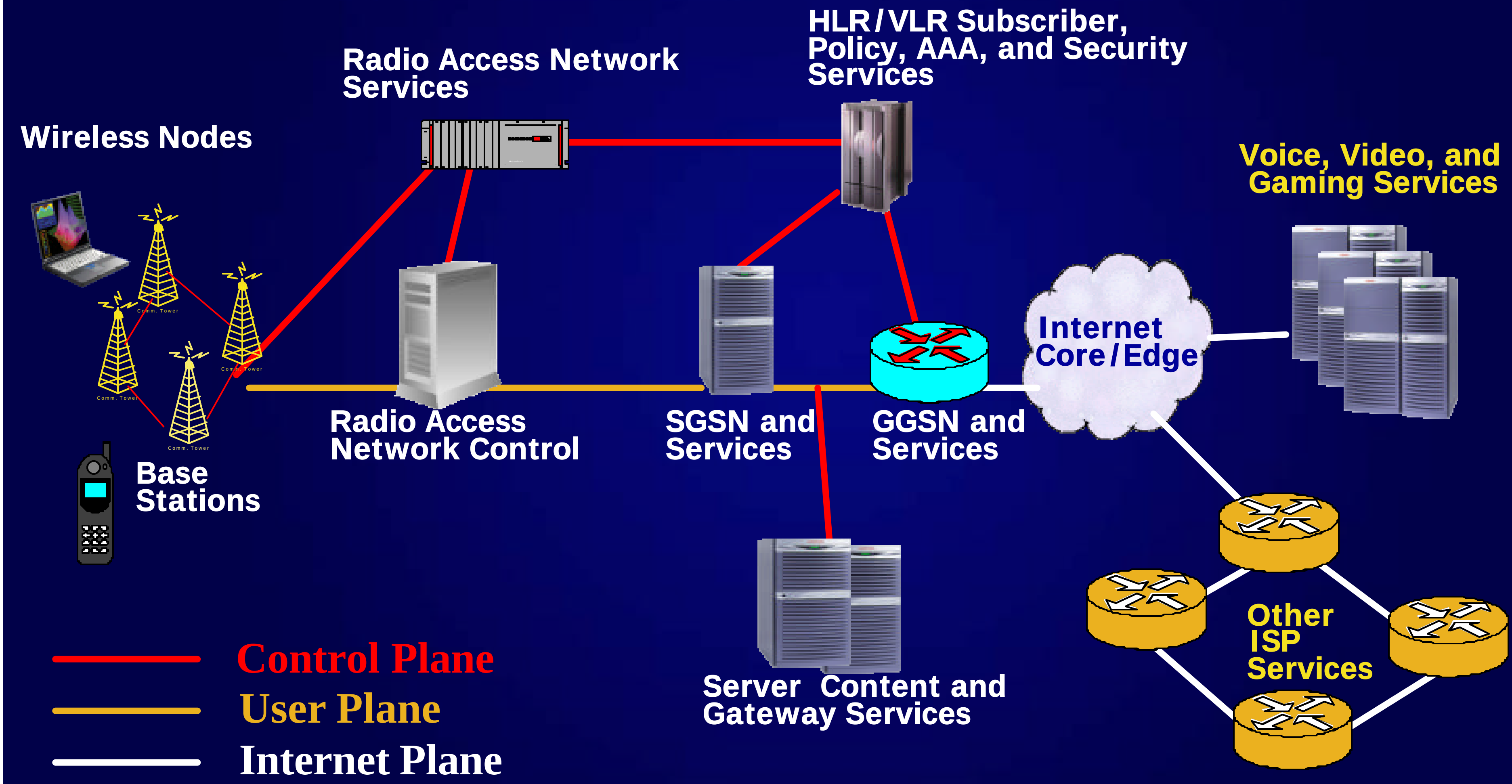
GSM Architecture



GSM/GPRS System Architecture



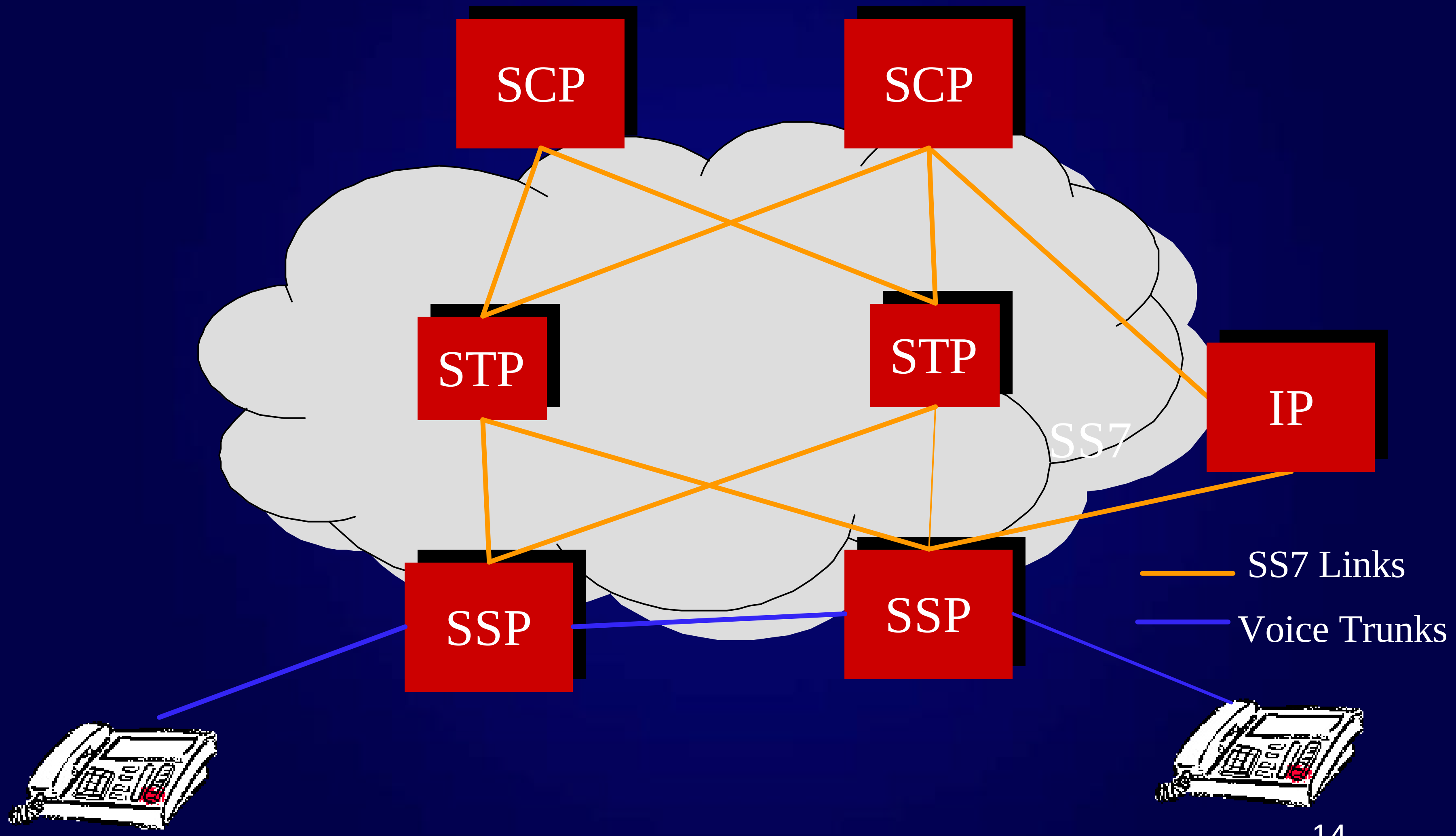
3G Wireless Architecture



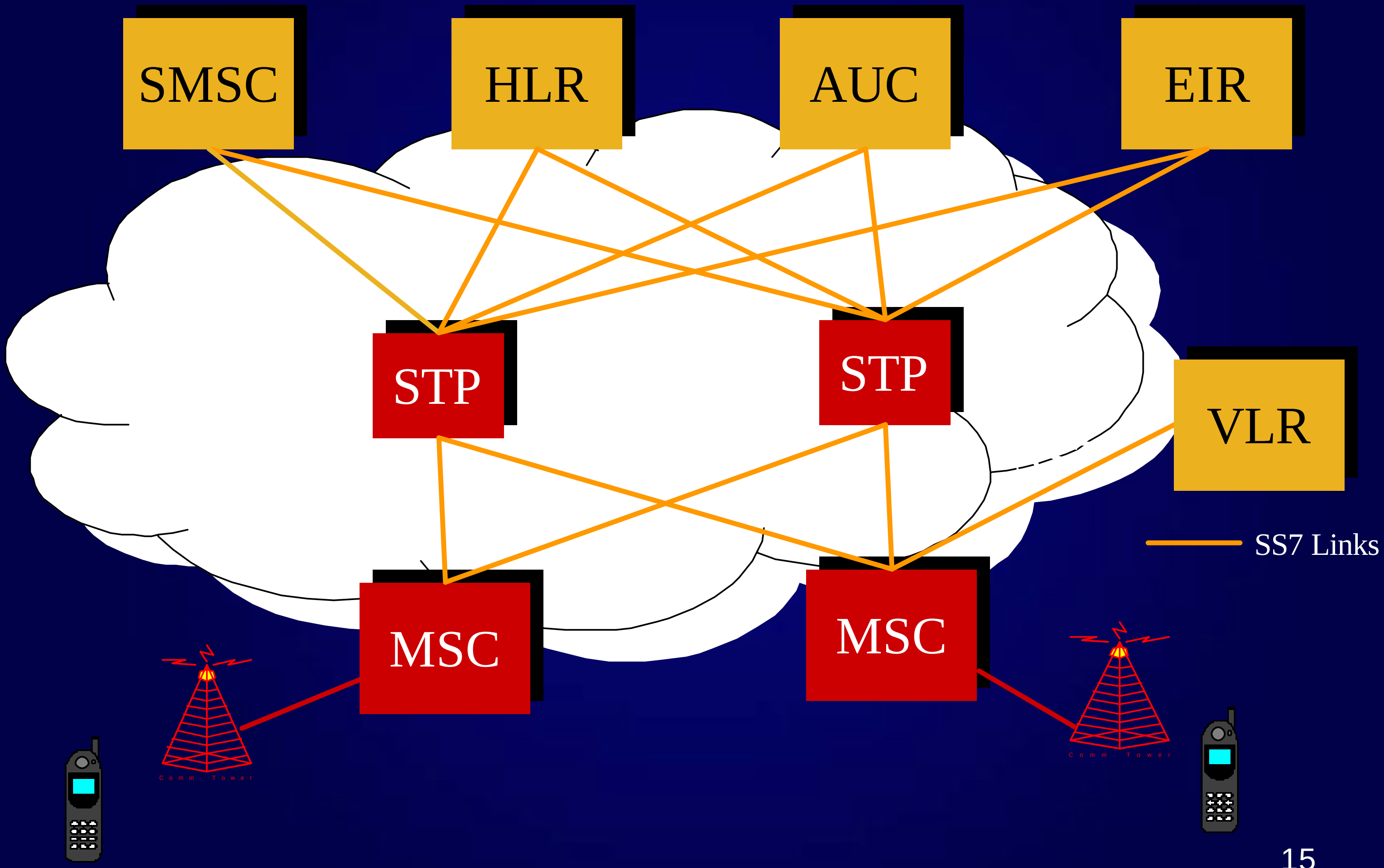
What about the Telephone Network Today?

- Circuit Based *not Packet Based*
- Signal and Voice Channels for communications
- These networks are evolving to IP
- But IP will have to coexist with the Signaling System #7 Protocol for coexistence
- So we need to discuss in this Wireless model briefly too !!!
- Because it has Internet Engineering work in process too

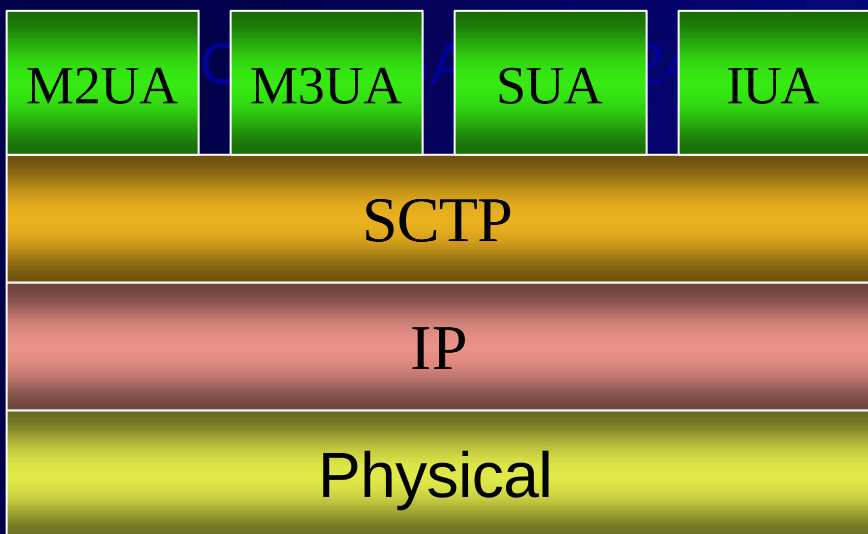
SS7 and the Wireline Network



SS7 and the Wireless Network



IETF SIGTRAN protocols suite



- SCTP
  - *Set of functions for reliable signaling transport*
- M2UA
  - *transport the MTP2 user (MTP3) over IP*
- M3UA
  - *transport the MTP3 users (SCCP, ISUP) over IP*
- SUA
  - *transport the SCCP user (TCAP) over IP*
- IUA
  - *transport the ISDN signaling (Q.931) over IP*

SCTP What is it?

- New Transport Protocol and architectural peer component to TCP and UDP above the IP network Layer
- It is NOT an application protocol or replacement for UDP or TCP
- Architected to be transparent to IPv4 or IPv6 network layer component
- IETF recommendations RFC 2960

Where SCTP will be added to a typical IP stack

Internet Server Applications

Network Utilities

Autoconfiguration of Addresses

RSVP

DNS

Network Mgmt

Routing Mgmt

Neighbor Processing

Tunnel Configuration

RSVP APIs

Network APIs

System Kernel APIs

Socket Layer

Protocol Control Blocks

Transport Layer TCP/UDP + **SCTP*****

IPv4/IPv6 Routing

Routing and Neighbor Caches

Virtual Tunnel Interfaces IPv4

Network Layer, ICMP, and Module Callout Switch IPv4/IPv6

Firewall Screening IPv4

RSVP/QOS Processing IPv4/IPv6

ARP IPv4

Neighbor Discovery IPv6

Adapter Interfaces and Processing

Network Interface Control, Queues, Mgmt, and Statistics

IPv6 Evolution

IPv4… A victim of its own success

- 1990
  - IPv4 addresses being consumed at an alarming rate, projections show:
    - Class B address space exhausted by 1994
    - All IPv4 address space exhausted between 2005 - 2011
  - Internet routing tables suffering explosive growth
  - Efforts started to address these problems

Interim measures

- CIDR (Classless Inter-Domain Routing)
  - Eased routing table growth for awhile
  - Multihoming punching holes in CIDR today
- Private addresses
  - Reduced pressure on address space, but…
  - Necessitated NAT, ALGs
  - Obstacle to renumbering
    - Example: merger of 2 companies using net 10
  - Additional management burden

NAT (Network Address Translation)

- Single point of failure
- Performance penalty
- Breaks applications that rely on End-2-End IP addressing (FTP, DNS, others)
  - Use ALGs
- Prevents End-2-End IPsec

ALGs (Application Layer Gateways)

- Example: www proxy servers
- Single point of failure
- Performance penalty
- Requires detailed knowledge of each application
  - Barrier to deployment of new applications
    - Barrier to growth

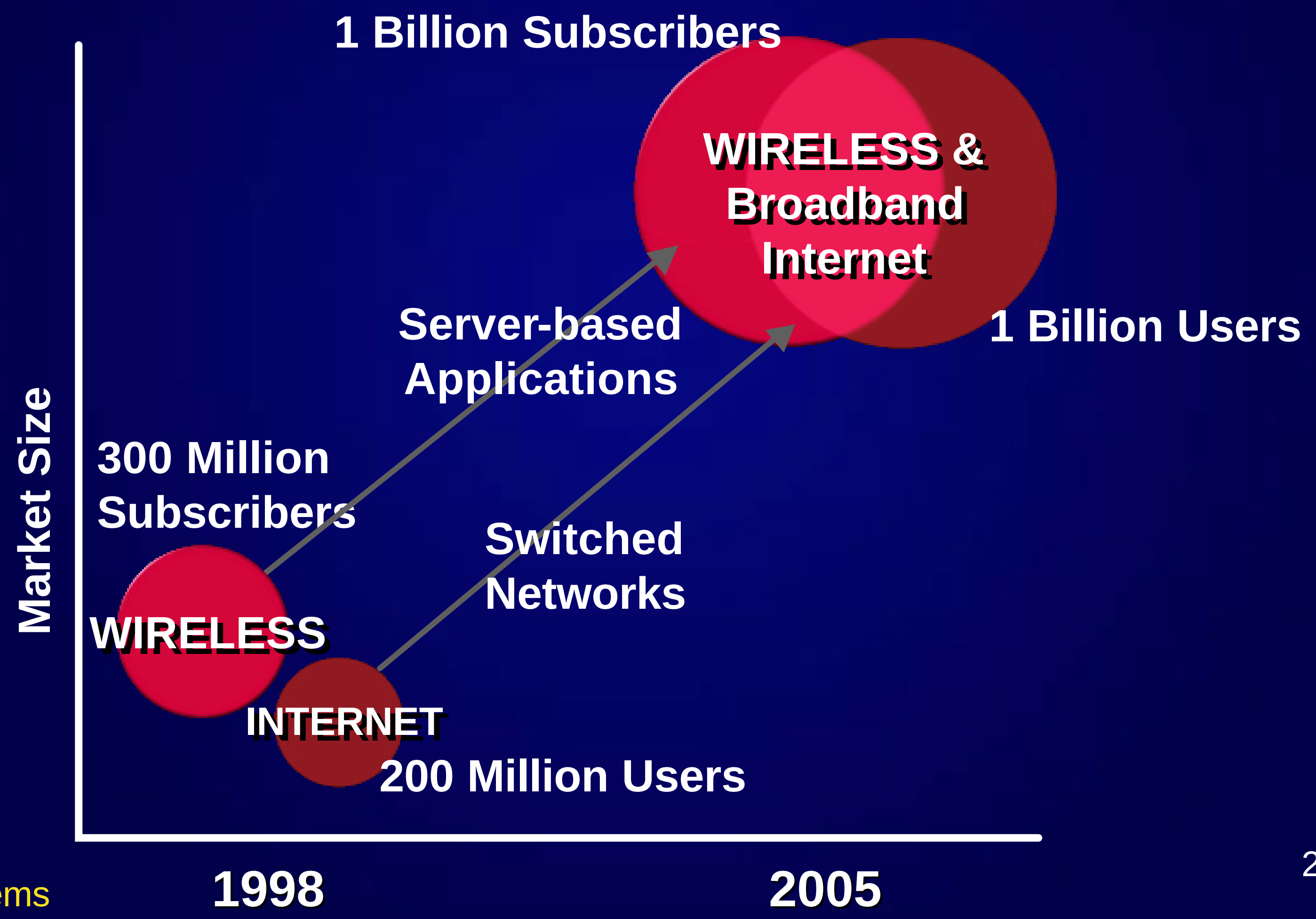
Interim measures helped, but…

- Address space consumption slowed, but Internet growth accelerated
- 1B mobile users by 2003
- 1B Internet users by 2005
- 90% of all new mobile phones will have internet access by 2003 (Morgan Stanley Dean Witter, May 2000)
- Projections of address space exhaustion by 2010, pain sooner (Europe and Asia)

… a longer term solution was sought

- 1991: Work starts on next generation Internet protocols
  - More than 6 different proposals were developed
- 1993: IETF forms IPng Directorate
  - To select the new protocol by consensus
- 1995: IPv6 selected
  - Evolutionary (not revolutionary) step from IPv4
- 1996: 6Bone started
- 1998: IPv6 standardized
- Today: Initial products and deployments

Growth of wireless and broadband Internet



Source Cisco Systems

IPv6 Immediate Benefits

- Increased Address Space
  - 128 bits
    - 2^128 is a really big number
  - Efficient addressing and routing topology
  - NAT is not required
    - Restores End-2-End IP addressing
- And while we're at it, we might as well make a few other improvements…

IPv6 Immediate Benefits (continued)

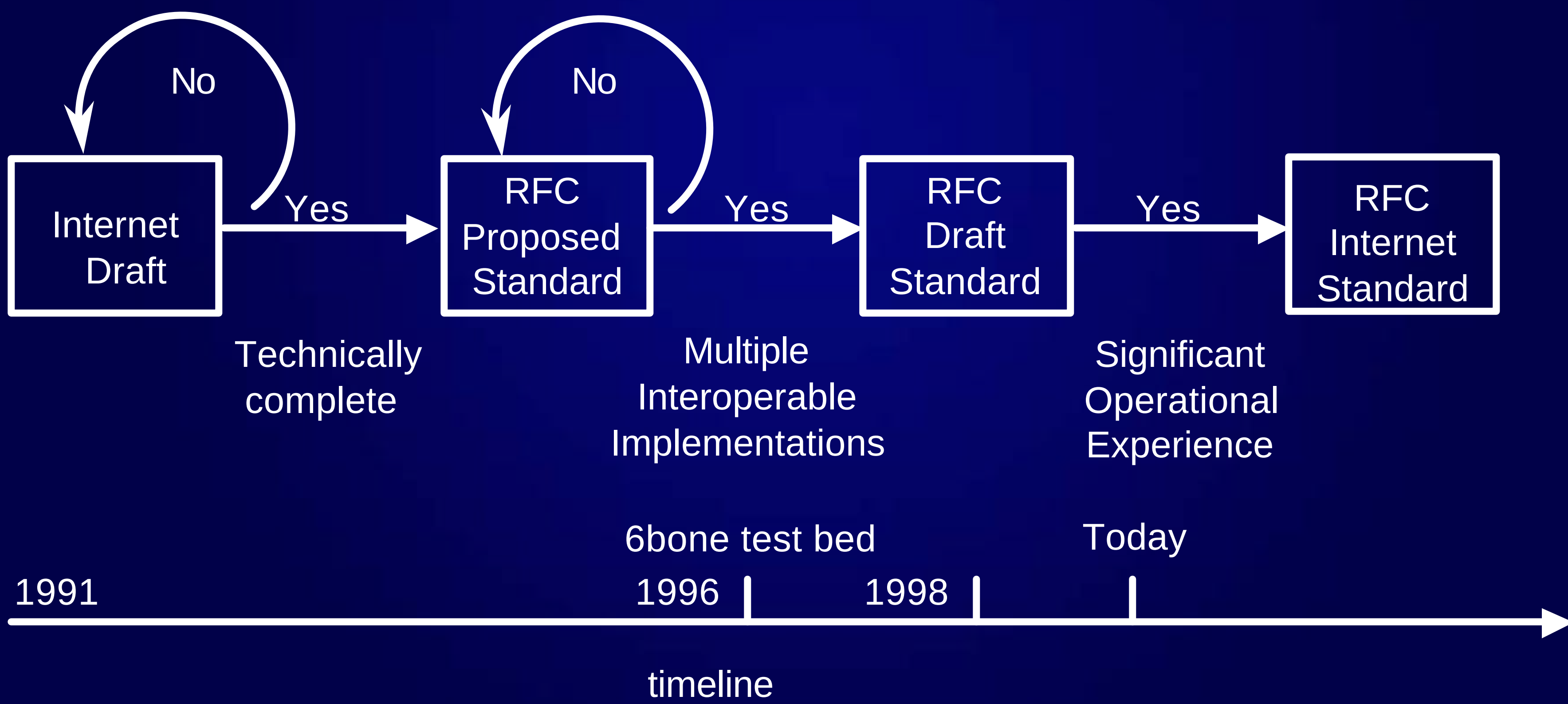
- Architecture
  - Simplified IP header
  - Optimized for 64 bit architecture
  - Efficient and extensible IP datagram
  - Improved host and router discovery
  - Improved multicast scalability
- Plug and Play
  - Dynamic Address Autoconfiguration (Stateless, Stateful)

IPv6 Immediate Benefits (continued)

- Enhancements for dynamic renumbering of networks
- Improved Mobile IP support
- Mandatory network-layer authentication and privacy
- Coexists with IPv4
- Other functions still evolving from the extensibility of the architecture

IETF Standardization status of IPv6

- Core specifications achieved Draft Standard status



IPv6 Industry Deployment Status

- Many products and Early Adopters kits available
- Internet Registries are handing out IPv6 addresses.
- Internet Service Providers are starting to provide IPv6
- IPv6 Forum (http://www.ipv6forum.com)
  - World-wide consortium including vendors and research/education community, to promote IPv6 by raising market and user awareness

IPv4 vs. IPv6 Header

0 bits	8	16	24 31
Ver	IHL	Service Type	Total Length
Identifier		Flags	Fragment Offset
Time to Live		Protocol	Header Checksum
32 bit Source Address			
32 bit Destination Address			
Options and Padding			

IPv4 Header
20 octets, 12 fields, including 3 flag bits
+ fixed max number of options

Changed

Removed

0	4	12 16	24 31
Version	Class	Flow Label	
Payload Length		Next Header	Hop Limit
128 bit Source Address			
128 bit Destination Address			

IPv6 Header
40 octets, 8 fields
+ Unlimited Chained Extension (options) Header

What has happened to our beloved IP stack?

Internet Server Applications

Network Utilities

Autoconfiguration of Addresses

RSVP

DNS

Network Mgmt

Routing Mgmt

Neighbor Processing

Tunnel Configuration

RSVP APIs

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System Kernel APIs

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Neighbor Discovery IPv6

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Network Interface Control, Queues, Mgmt, and Statistics

IPv6 Wireless Advantages

- Extended Address Space
- Automatic Node Discovery on visited Network
- Stateless Address Configuration
- Extensions to support Mobile Networking, Routing, and Mobile Home Agent Router
- Dynamic Renumbering of Mobile Terminal on visited Network LAN
- Statefull Address and Parameters Configuration
- IPv6 in *shipping* Products today ……………….

Mobile IP Evolution

What's Driving IPv4 / IPv6 Mobility

- The Need
  - Continuous connectivity to moving systems
- Increasing numbers of systems are moving
  - Increasingly mobile work force
  - Increased need to remain "Connected"
  - Wireless communications technologies are becoming widely available
  - and many more…

Being Mobile is becoming NORMAL

Today’s World - Mobile IP Constraints

- The Internet world was designed for static connections
  - Mobile IP was designed with this reality
    - No modifications to existing routing infrastructure and protocols
    - Inter-operability with TCP/IP protocol suite
    - Good scaling properties

Internet Principles

- IP address defines
  - “where the node is connected to”
- Established network session requires the following 4-tuple to be constant:
  - Source IP Address, Source Port Number, Destination IP Address and Destination Port Number

Changing any of these
will cause the connection to be broken

Mobile IP Challenge and Solution

- Mobile IP Challenge
  – Host IP address must be retained regardless of “where the node is connected to”

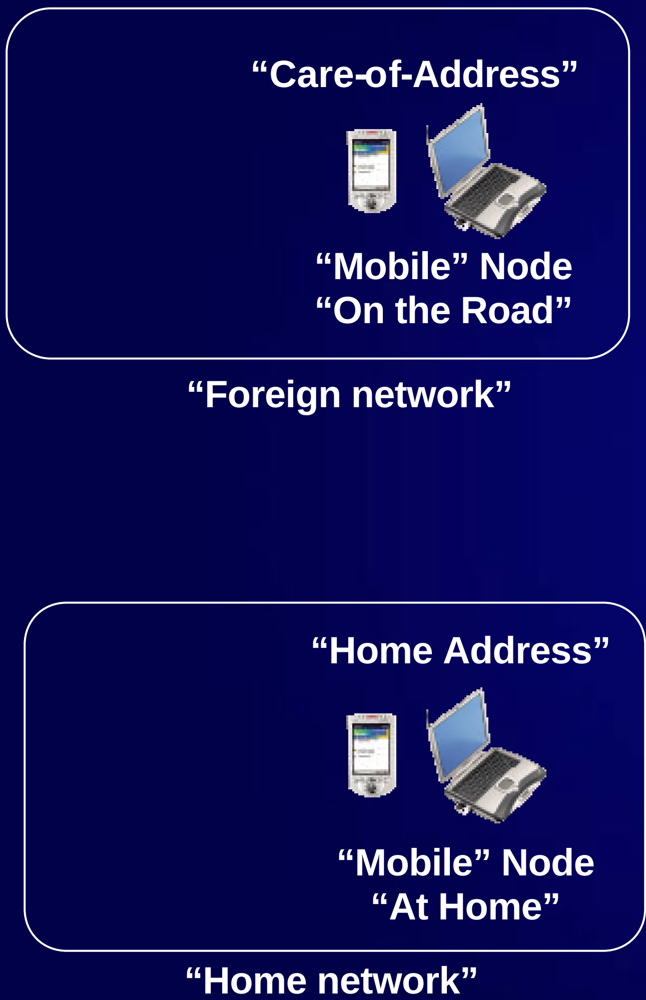
  BUT

  – If the host moves retaining its IP address means routing will fail
- Mobile IP solves this problem by:
  – Retaining its “home” IP address

  AND

  – Borrowing a “care-of address” on the subnet the node happens to be connected to.

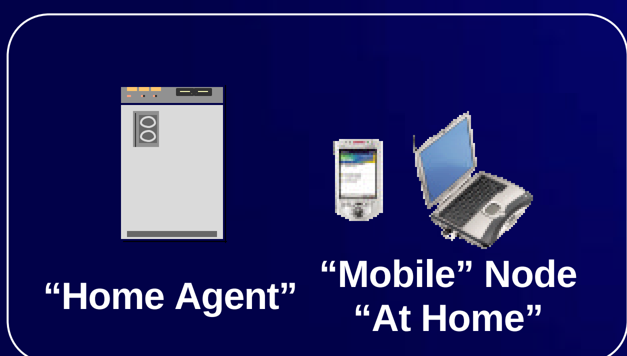
Mobile IP Terminology



- Mobile Node (MN)
  - Maybe “At Home” on “Home” network
    - Home Address when at home
  - Maybe “Away from Home” on a “Foreign” network
    - Care-of Address when connected to a “Foreign” link
- Correspondent Node (CN)
  - A node corresponding with Mobile Node

Mobile IP Terminology - Agents, Bindings

"Foreign network"



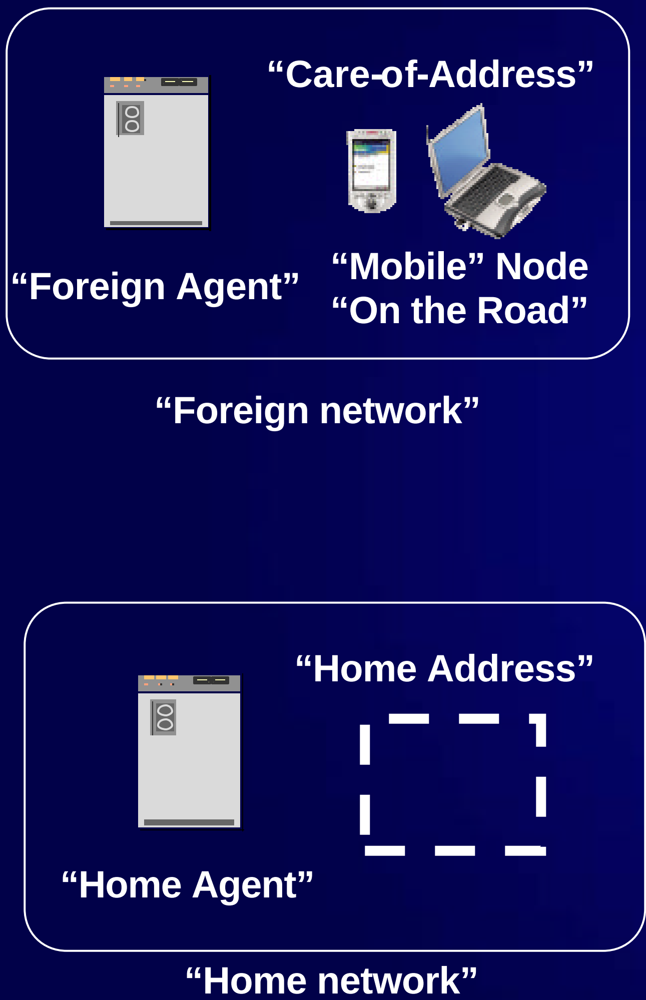
"Home network"

- Mobility Agents
  - Home Agent
  - Foreign Agent (v4 only)
- A "Binding"
  - Association (cached by other nodes) between
    - Home Address
    - Care-of Address

Agents for Mobile IPv4

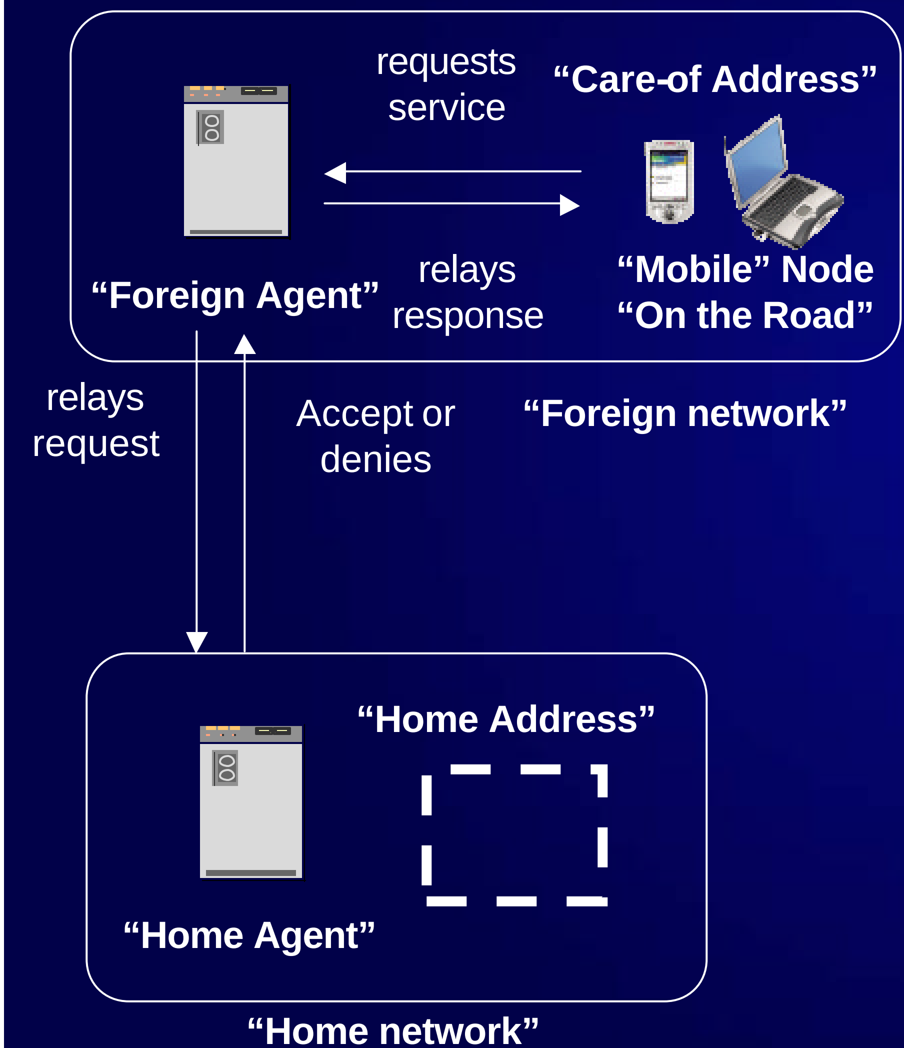
- Home Agent - A router on home network
  - Maintains current location information
    - Uses proxy and gratuitous ARP mechanisms
  - Tunnels packets to MN when not at home
- Foreign Agent – A router on Foreign network
  - Provides routing services to registered MN
  - De-capsulates and delivers packets to MN
- Agent Discovery (extension to ICMP router discovery)
  - Home Agents and Foreign Agents may advertise their availability
  - A newly arrived MN can send Agent Solicitation

Obtaining an IPv4 Care-of-Address



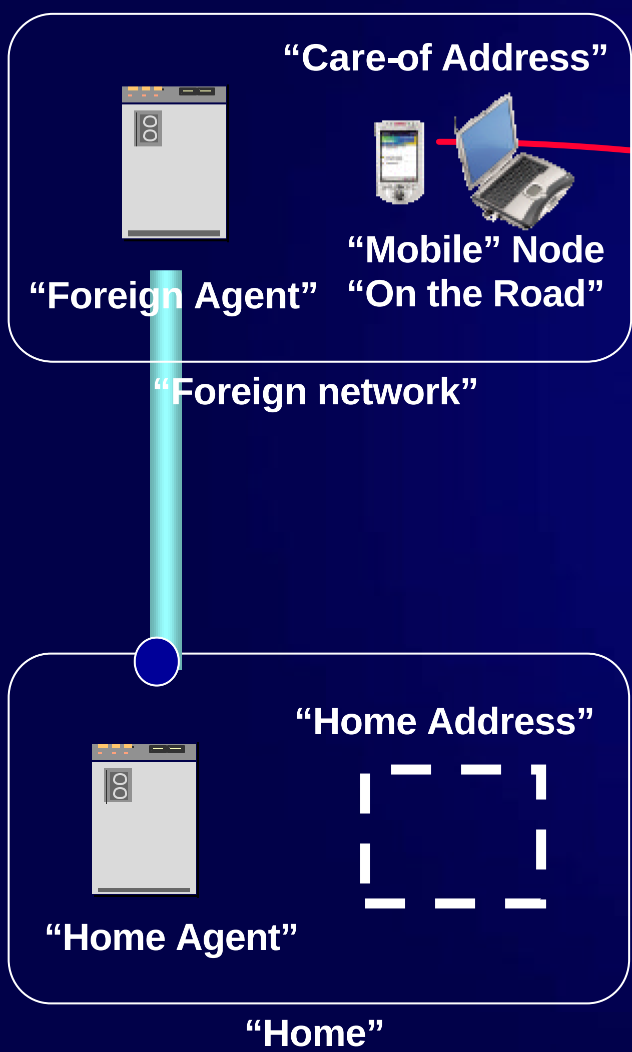
- Agents advertise their presence via Agent Advertisement messages
- MN receives Agent Advertisements and determines whether it is on its home network or a foreign network
- If on a foreign network, MN obtains a Care-of Address
  - Care-of Address can be determined from a foreign agent's advertisements (one of IP address of the Foreign Agent)
  - or by some external assignment such as DHCP

Registration of an IPv4 Care-of Address



- MN registers its new Care-of Address with its Home Agent through exchange of a Registration Request and Registration Reply message
  - Uses UDP (port 434)
  - via (possibly) a Foreign Agent
  - Authenticated with Mobile-Home Authentication Extension (statically configured mobility security association)

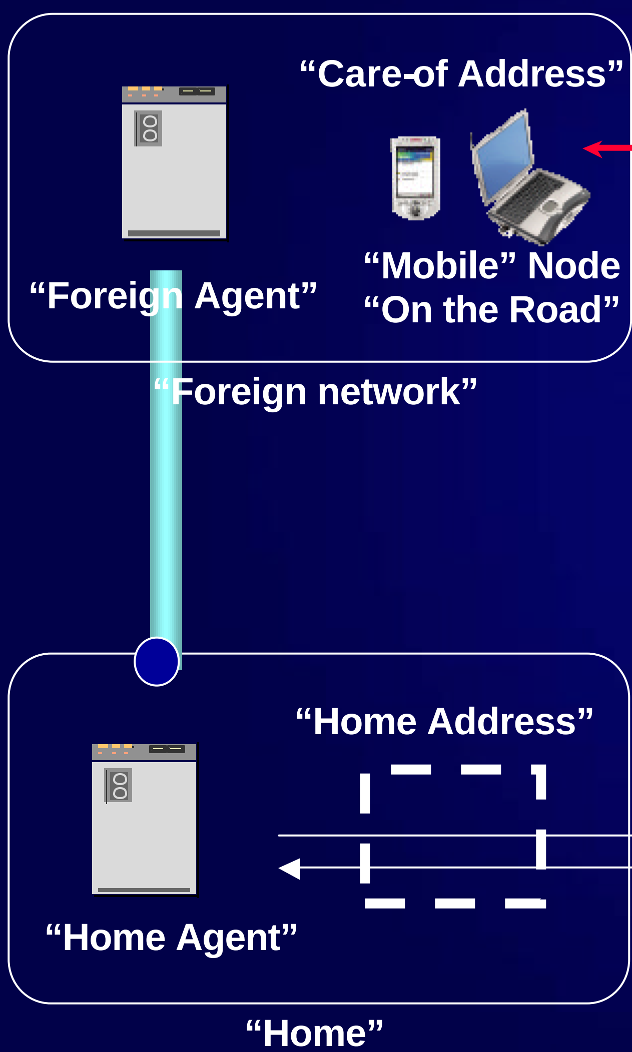
Mobile IPv4 Communication with CN

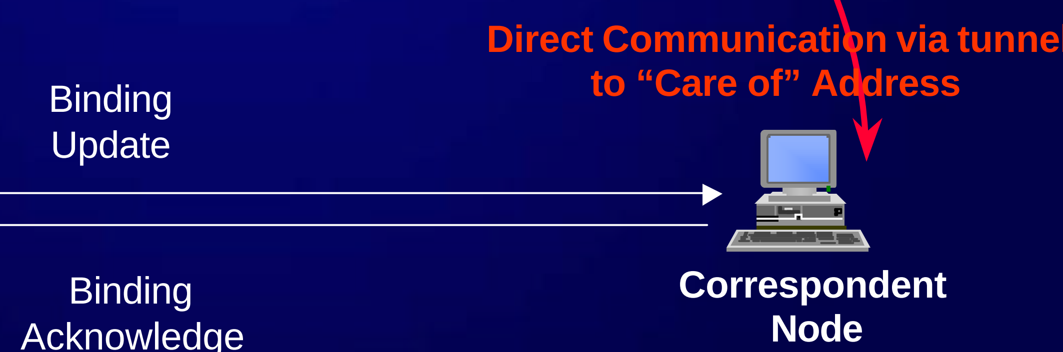


- Packets sent to MN home address
  - Delivered to Home Network using standard IP routing
  - Intercepted by Home Agent
  - Encapsulated, delivered via tunnel to Care-of Address
- Packets sent from MN
  - Delivered to their destination using standard IP routing mechanisms
- Triangle (non-optimal) routing
  - Home Agent bottleneck
  - Increased network utilization

Mobile IPv4 - Route Optimisation

- Allow correspondent hosts to know the care-of address of the mobile node
  - When a Home Agent intercepts a packet for a MN that is away, it sends a “binding update” message to the correspondent
- Correspondent then updates its binding cache and tunnels all future packets directly to the MN’s Care-of Address





Requires modified correspondent, and security associations with home agents

Mobile IPv4 issues

- Requires infrastructure deployment ahead of use
  - Home Agents, Foreign Agents
- Requires correspondents to be modified for route optimization
- Lack of sufficient number of IPv4 addresses to fully deploy necessary infrastructure

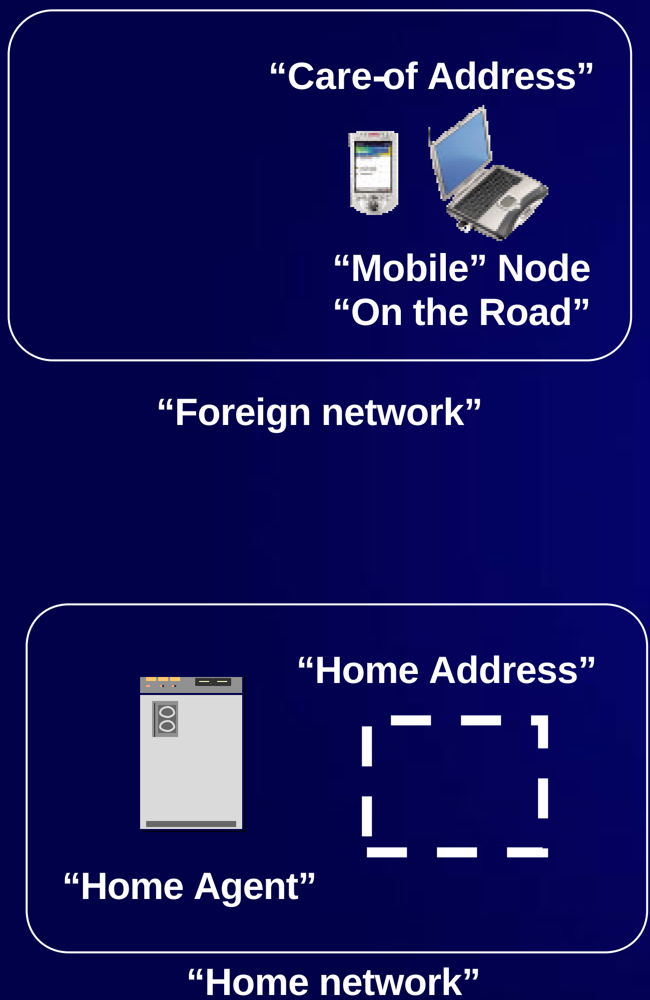
Mobile IPv6

- Based on core features of IPv6
  - IPv6 was designed to support Mobility, not an “add-on”
    - IPv6 Header Structure
    - IPv6 Address Autoconfiguration
    - IPv6 Security
    - Tunnelling
  - All IPv6 networks are Mobile IPv6 ready
  - All IPv6 nodes are Mobile IPv6 ready

Agent for Mobile IPv6

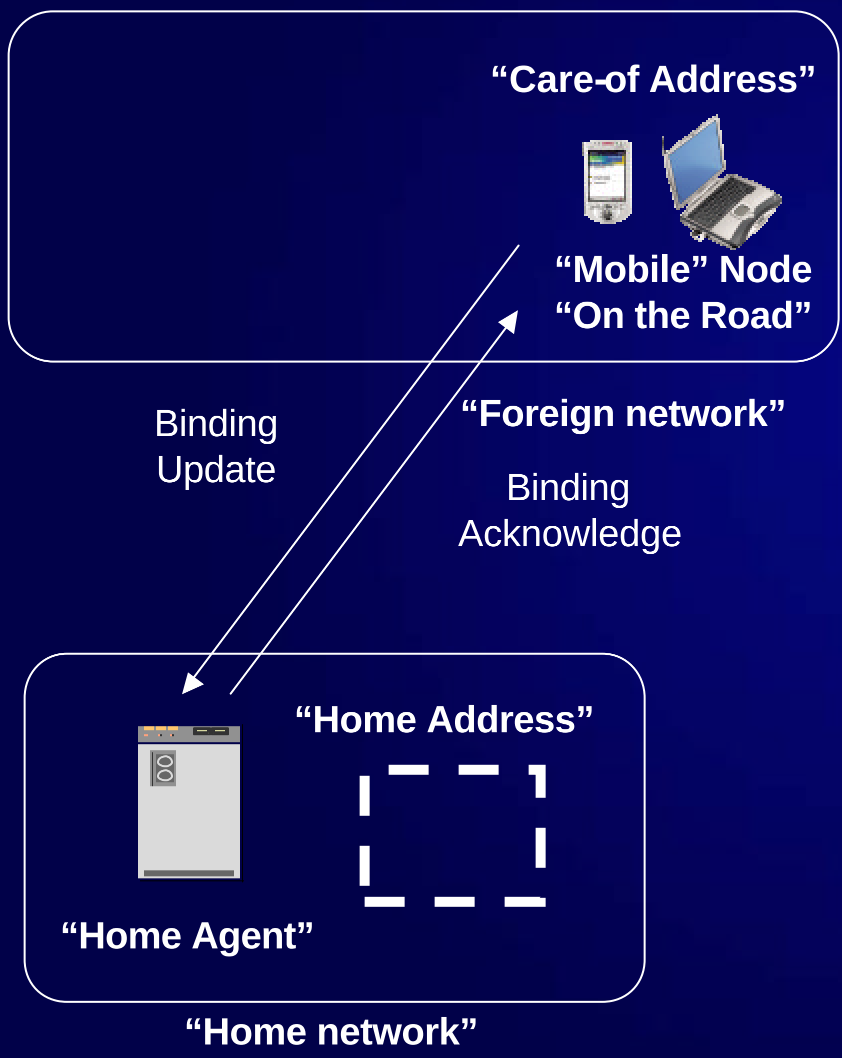
- Home Agent - A router on home network
  - Tunnels packets to MN when away from home
  - Maintains current location information for the MN
    - Uses Proxy and gratuitous neighbor discovery
- Dynamic Home Agent Discovery
  - Sends Home Agent Address Discovery Request message to the Mobile IPv6 Home Agent's anycast address
  - One of the Home Agents responds to the MN with a Home Agent Address Discovery Reply message, giving a list of Home Agents

Obtaining an IPv6 Care-of Address



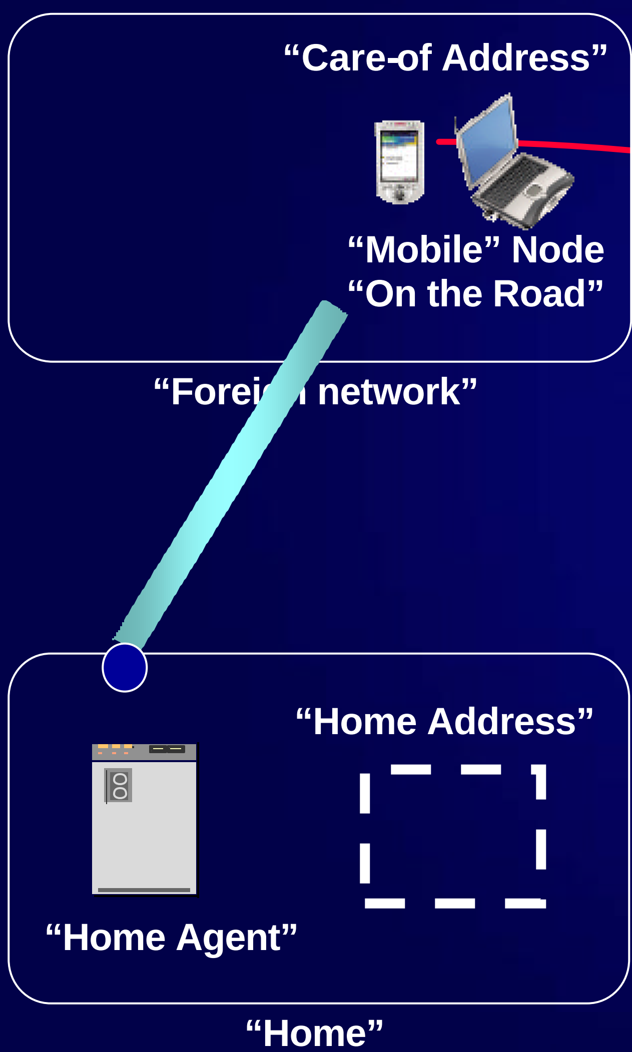
- When connected to a “Foreign Link”
  - A MN acquires its Care-of Address through normal IPv6 stateless or stateful Address Auto configuration and Neighbor Discovery
- No “Foreign Agent”
  - IPv6 Neighbor Discovery and Address Auto configuration allow hosts to operate in any location without any special support

Registration of an IPv6 Care-of Address



- MN sends its new Care-of Address to its Home Agent (and others) through Binding Update messages
  - IPv6 options may be included in any IPv6 packet
  - Security via mechanism TBD

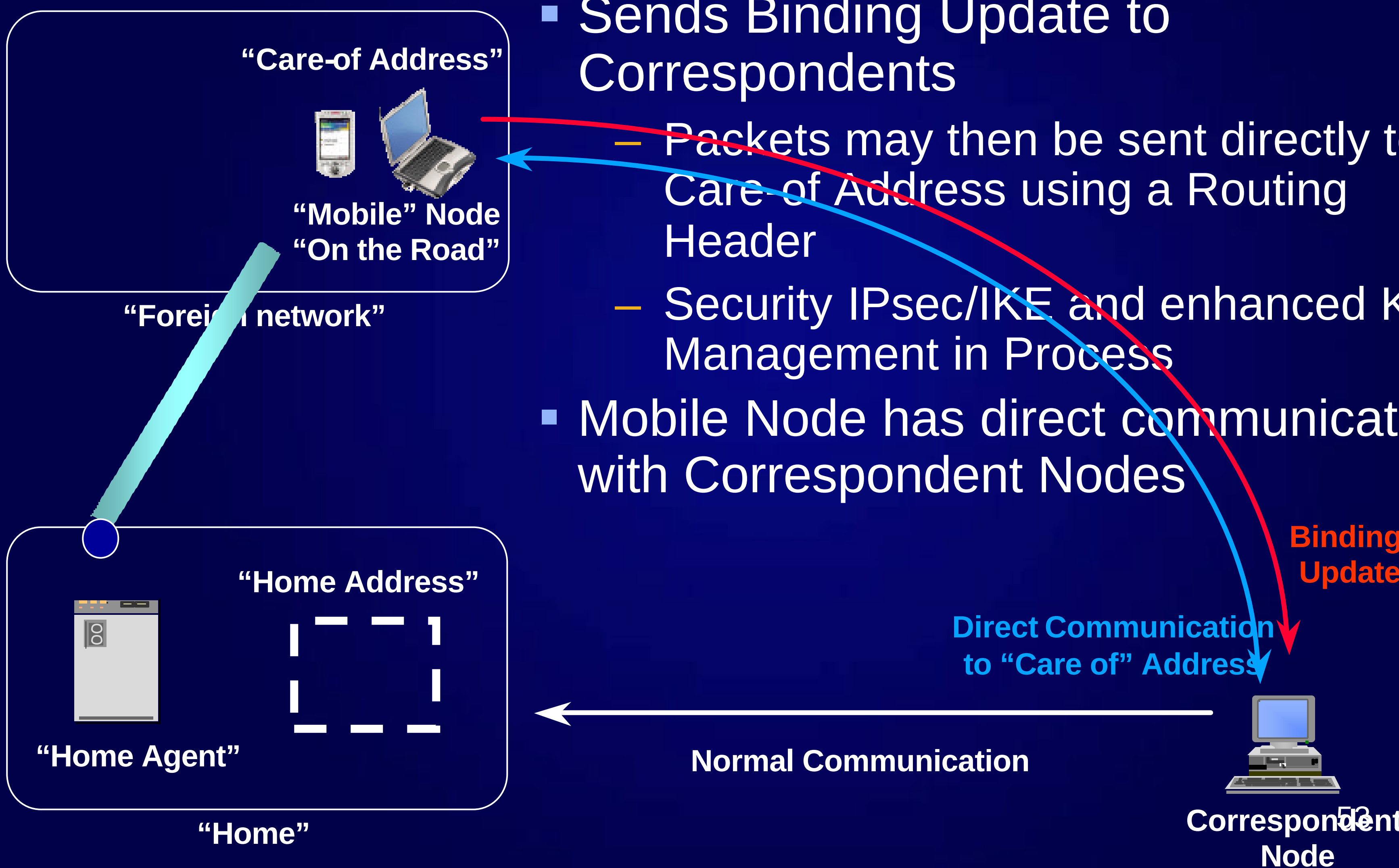
Mobile IPv6 Communication with CN



- Packets sent to MN home address
  - Delivered to Home Network using standard IP routing
  - Intercepted by Home Agent
  - Encapsulated, delivered via tunnel to Care-of Address
- Packets sent from MN
  - Source address is Care-of Address, Home Address carried in Home Address destination option header
  - Delivered to their destination using standard IP routing mechanisms

Mobile IPv6 - Route Optimisation Built In

- Sends Binding Update to Correspondents
  - Packets may then be sent directly to Care-of Address using a Routing Header
  - Security IPsec/IKE and enhanced Key Management in Process
- Mobile Node has direct communication with Correspondent Nodes



Mobile IPv6 vs. Mobile IPv4

- Fully integrated into the rest of IPv6
- Requires little infrastructure
  - No “Foreign Agent”
- No single point of failure (Home Agent)
- More Scalable : Better Performance
  - Less traffic through Home Link
  - Not dependent on one or two busy Home Agents
  - Traffic Optimisation - Less redirection / re-routing
- Relies on mandatory parts of the base protocols

Mobile IP Node Handoff is the Complexity

- Home Agent
  - Acts as proxy for Mobile Node while away from Home
  - Tunnels packets from Correspondent Nodes to Mobile Node
  - Keeps location of Mobile Node as it moves
  - Forwards Home Network configuration to the Mobile Node
- Correspondent Node
  - Point of Services for the Mobile Node
  - Understands how to communicate to the Mobile Node
    - Directly through Route Optimizations
    - Indirectly through the Mobile Nodes' Home Agent
- Mobile Node
  - Usually a client that moves between Wireless Cells or Access Points
  - Maintain knowledge of Home Agent and Correspondent Nodes

Macro and Localized Mobility Management

- Macro Mobility
  - Communications from the Mobile Node to the Home Agent Node
  - Communications from the Mobile Node to the Correspondent Node
  - Communications from the Correspondent Node to Home Agent
  - Communications update for Mobile, Home Agent, and Correspondent
- Localized Mobility Management
  - Communications to address Mobile Terminal Movement
    - Fast Handoff (reduce packet delay)
    - Smooth Handoff (reduce packet loss)
    - Seamless Handoff == Fast+Smooth
  - Communications to handle Context Transfer
    - Buffer packets during movement detection
    - Forwarding packets after movement completed

Mobile IPv6 Advantages

- Large Address Space
  - Can support billions of Mobile Devices
  - Distributed hierarchy with NAT won’t work and not deployed
- Automatic Link Configuration
  - Neighbor Discovery on home and visited networks
  - Stateless and Statefull Address Configuration
- Destination Options removes need for signal and user plane
  - Binding Updates to identify location
  - Registration Updates to identify movement
- Routing is Optimized because of Binding Updates

Mobile IPv6 continued Evolution

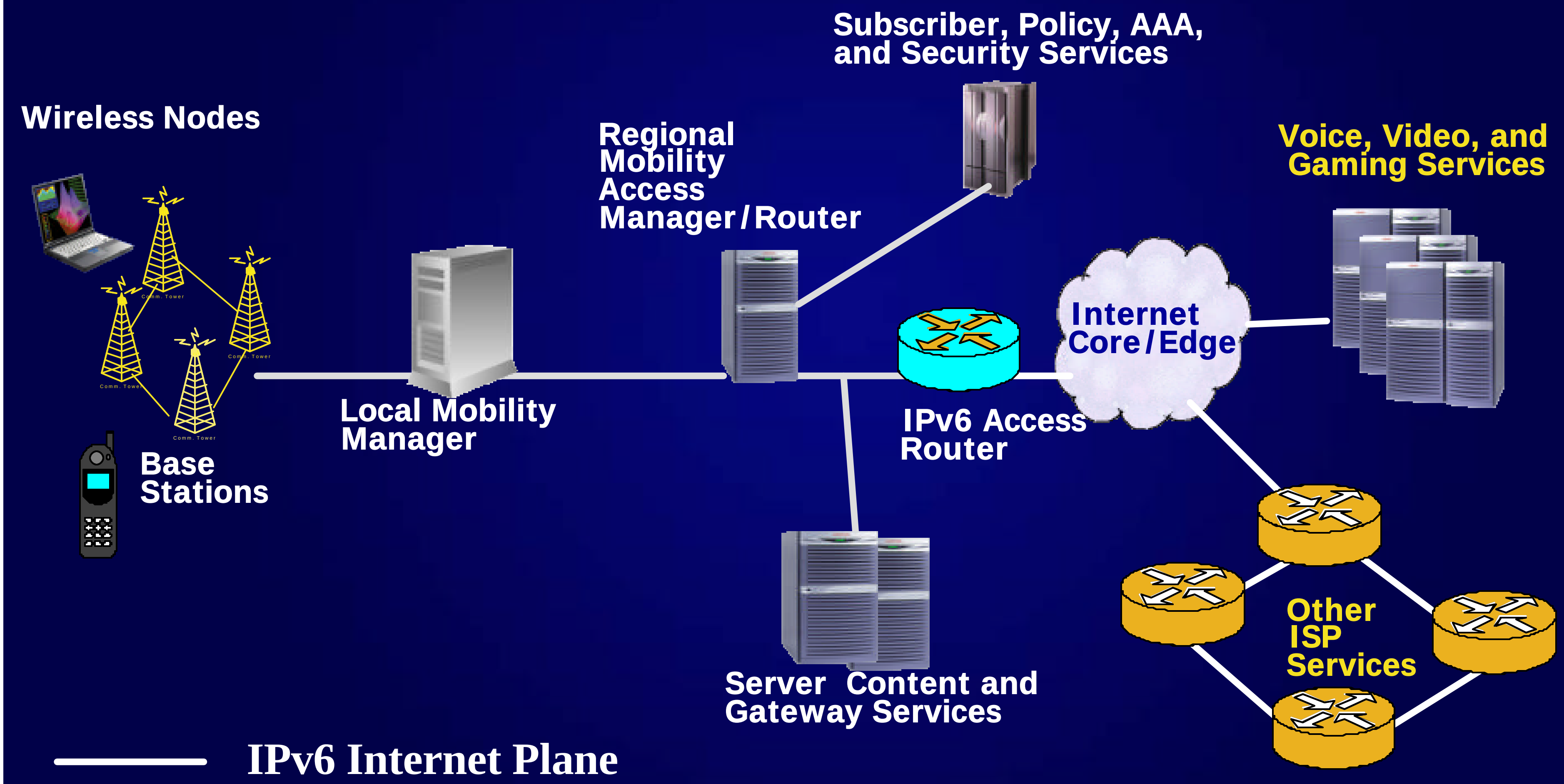
- Seamless Handoffs
- Header Compression
- Authentication, Accounting, and Authorization (AAA)
- Enhancements to Transport Layer Protocols
- Quality of Service (QOS)
- Local Mobility Management
- Mobile Ad-Hoc Networking

The Future: Wireless and Wireline Integrated

Full Seamless IP Wireless to the Internet

- IPv6 will be Mandatory for full Evolution to the Internet
- Radio Access Network parts will become IP Access Routers and Gateways
- Mobile IPv6 will be the architecture for Handoffs and to access Location Based Services
- Local Mobility Agents will distribute the processing of Wireless Handoffs and Integration of Wireless to Wireline access
- AAA will become the prime security, billing, and subscriber database infrastructure

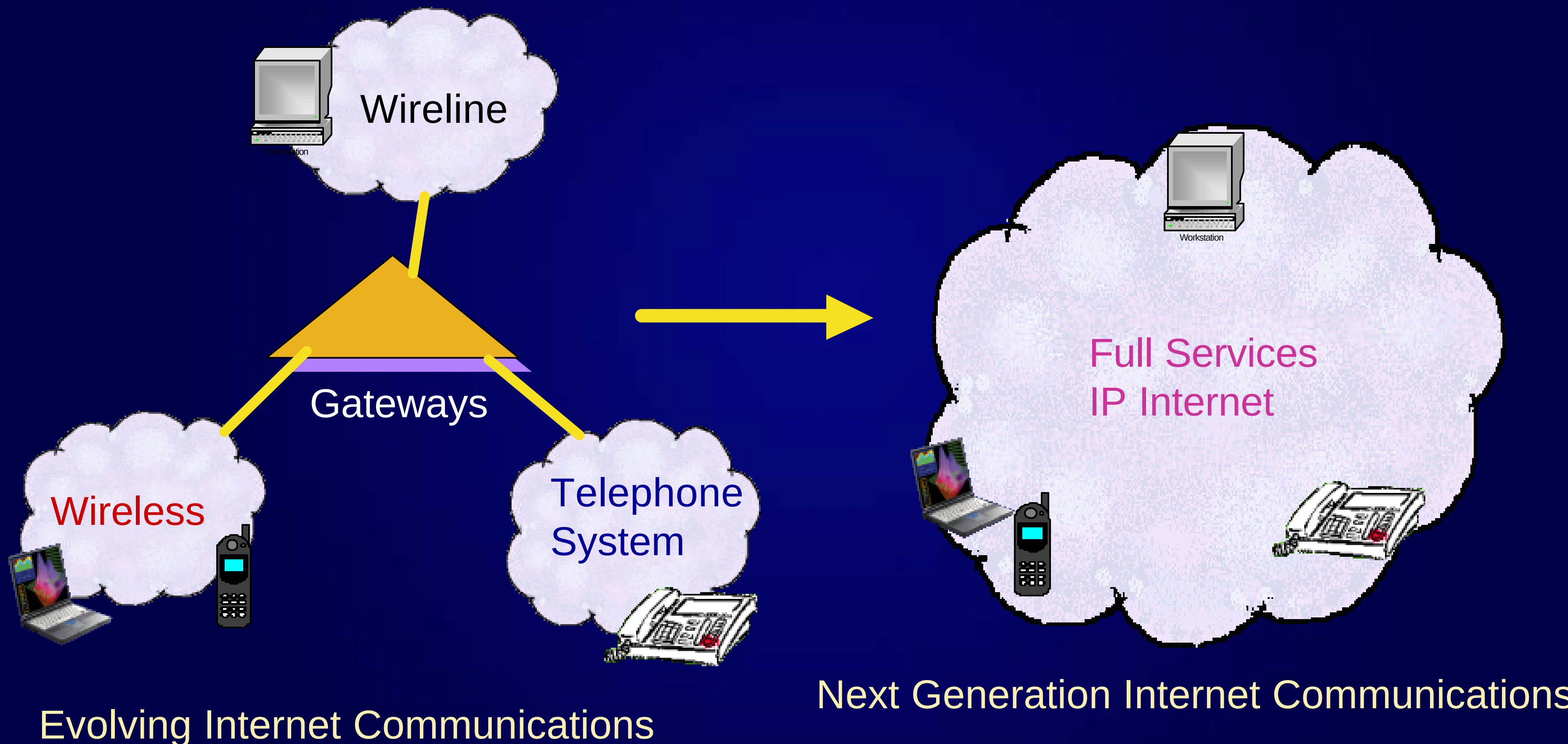
Full Seamless IP Wireless Services



The Benefits of this Evolution

- Internet End-2-End Model is restored
  - NAT is not required
  - Tunnels are not required
  - **New** End-2-End Applications can now evolve again
  - Internet Access will be pervasive and cheaper for underdeveloped nations and the have-nots in the world
- Internet End-2-End Security is restored
  - Security is between you and your ISP and your peer on the network
- Complexity is reduced by removing the signal planes from previous Wireless and Telephone network protocols
- Seamless mobile computing on the Internet is achieved because of IPv6 and Mobile IPv6 Routing
- Wireline, Wireless, and Telephone System is integrated and manageable as a single network domain

The Internet Evolution



Thank You

Questions??