Hierarchical Mobile IPv6 and Dynamic Hierarchy

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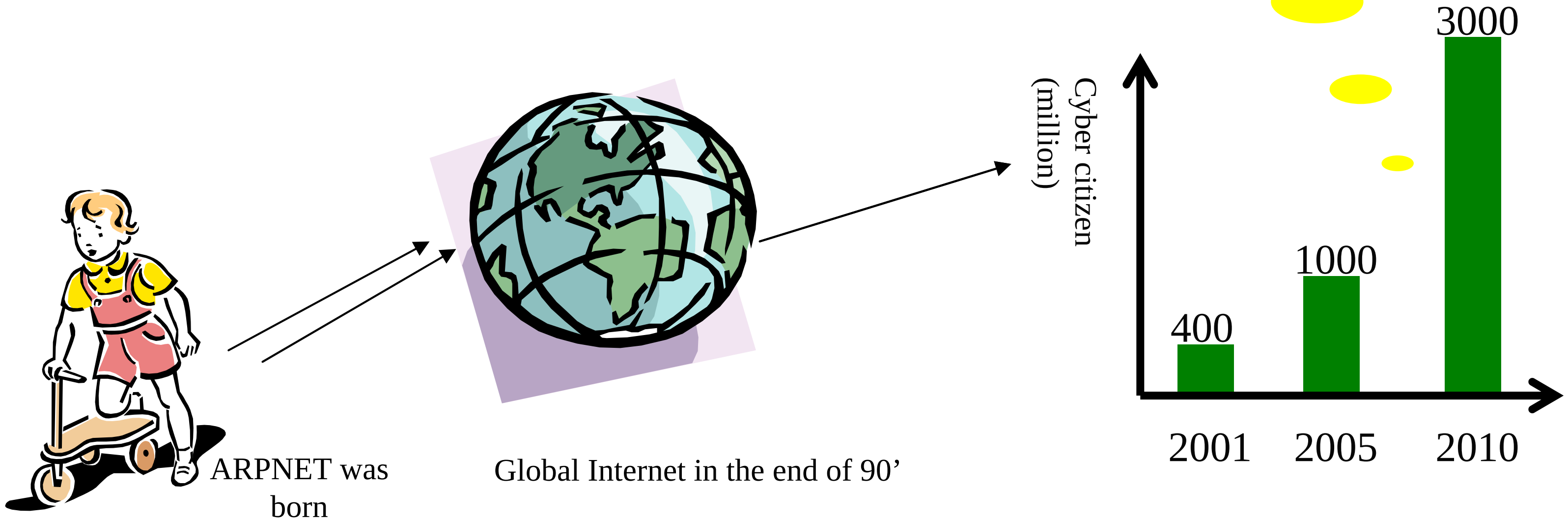
Outline

- Background of IPv6 and Mobile IP
- Performance Evaluation of Hierarchical Mobile IPv6
- Adaptive Mobility Management Scheme (AMMS)
- Dynamic Hierarchy by Extending AMMS with Multi-MAP
- Further thinking

1.Background of IPv6 and Mobile IPv6

- IP networks experience three eras
  - ✓ computer era
  - ✓ information era
  - ✓ personal communication era

IP addresses were exhausted at the speed of 60-80 billion per year from 1995

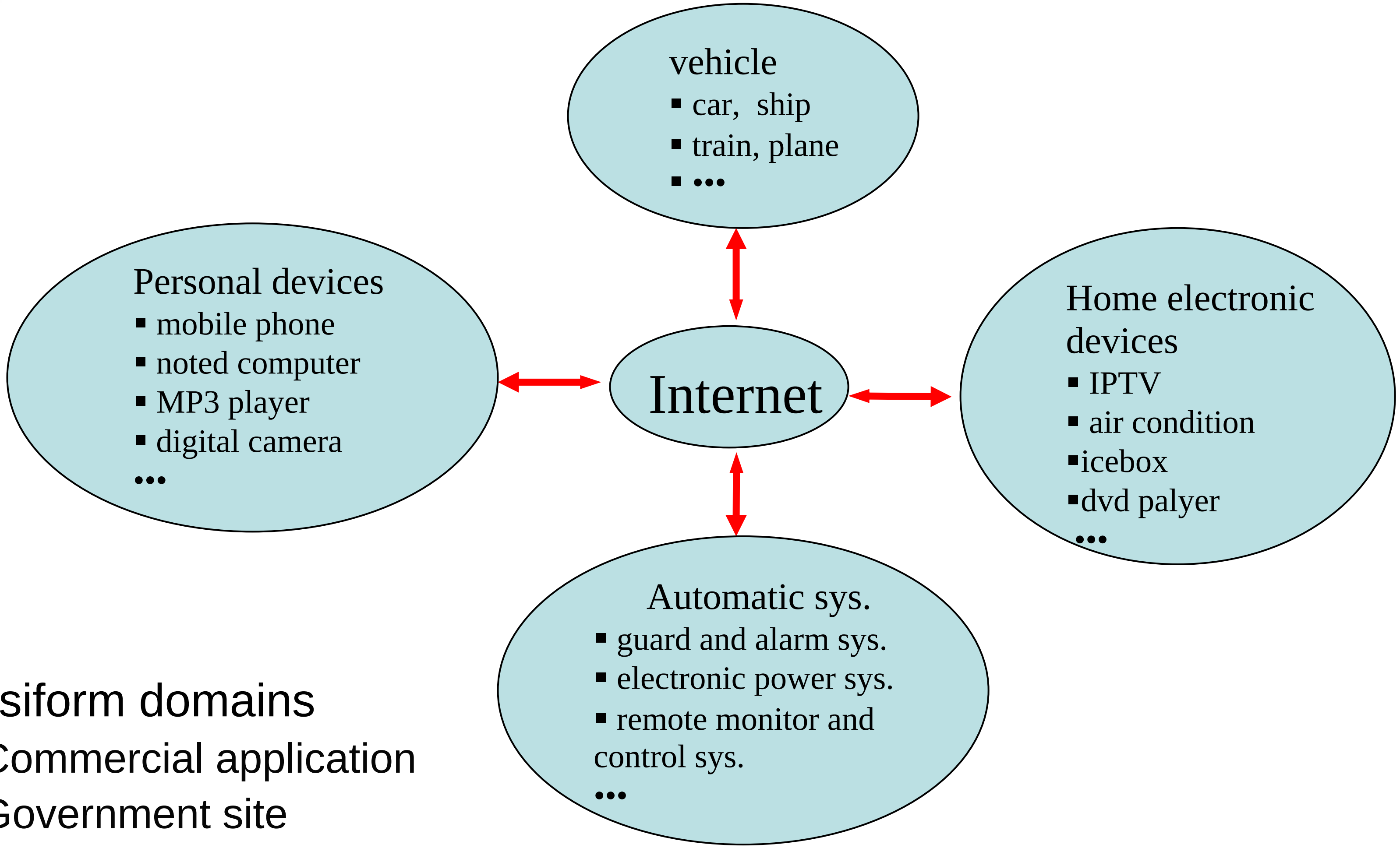


!!! Some new changes arriving

❑Some issues of the current IPv4

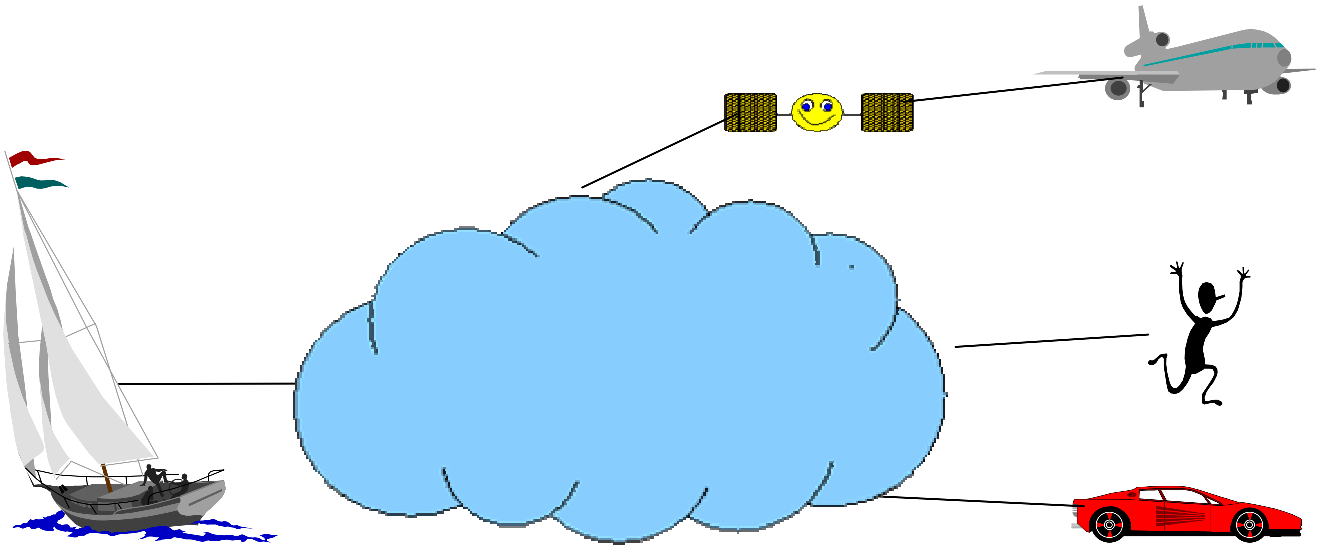
- Limited IP address space
  - –32 bits length
  - –Bad management modes, A, B, C, D classes
  - –Improved by CIDR, NAT, but
    - Complexity increased
    - End-to-end property destroyed
- Low efficiency of routing
  - –Variable length of IP header
  - –Lack of efficient IP address management, …
- Lack of security and mobility
  - –Original networks is trusted, but currently trustworthiness is missing
    - Original users----researcher, officer, students, ….
    - Current users----hacker, business man, spy, destroyer also included
  - –Internet is migrating from fixed networks to hybrid and heterogeneous networks, mobility is required

❑IP addresses will be exhausted



- Diversiform domains
  - –Commercial application
  - –Government site
  - –No-benefit site

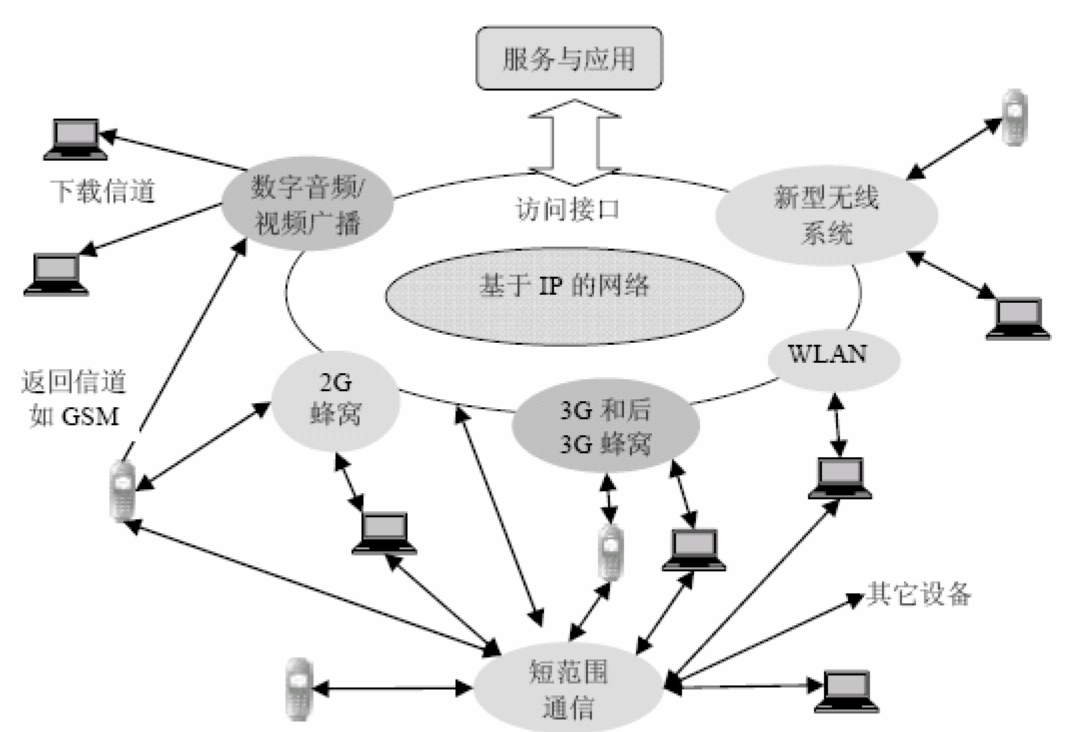
❑Mobility is necessary



http://www.inrialpes.fr/planete/people/ernst/Welcome.html

- The recent emergence of mobile communication and wireless access in IP network provides an incentive to design an efficient mechanism to enable an IP terminal keep existing communication while changing its access to subnet.

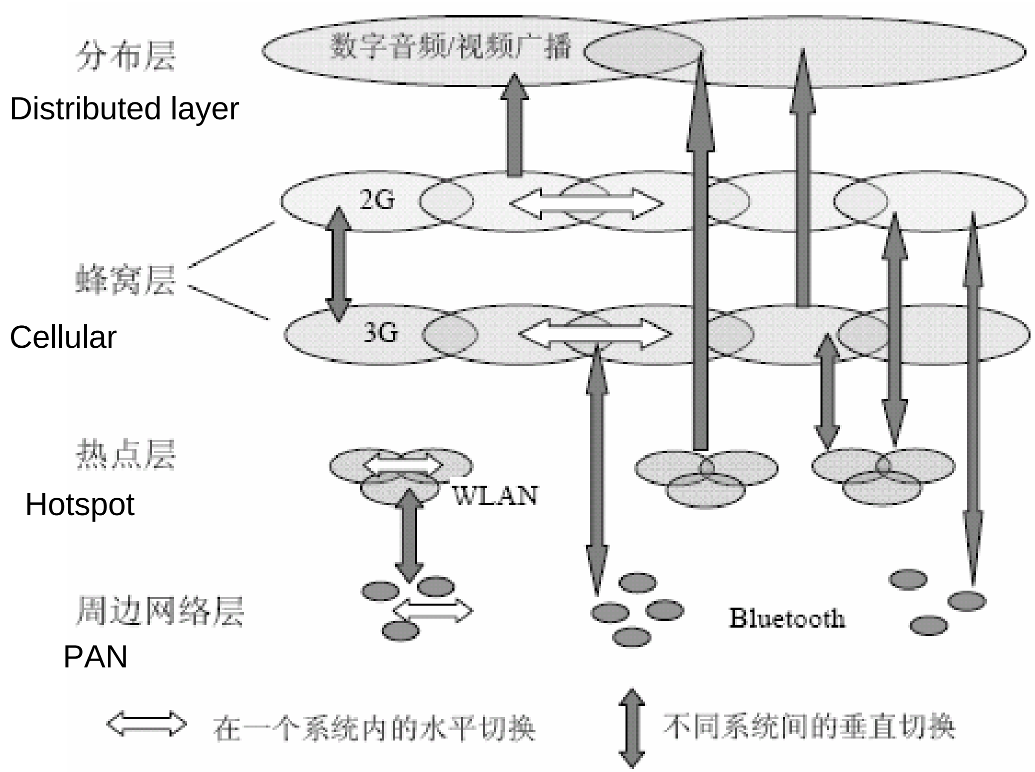
❑Mobility is necessary



The integrated framework **based IP networks** of future heterogeneous wireless access networks

http://www.ntpo.org.tw/b3g_2.htm.

❑Mobility is necessary



horizontal handoff, happen in the same system   Vertical handoff, happen in different system

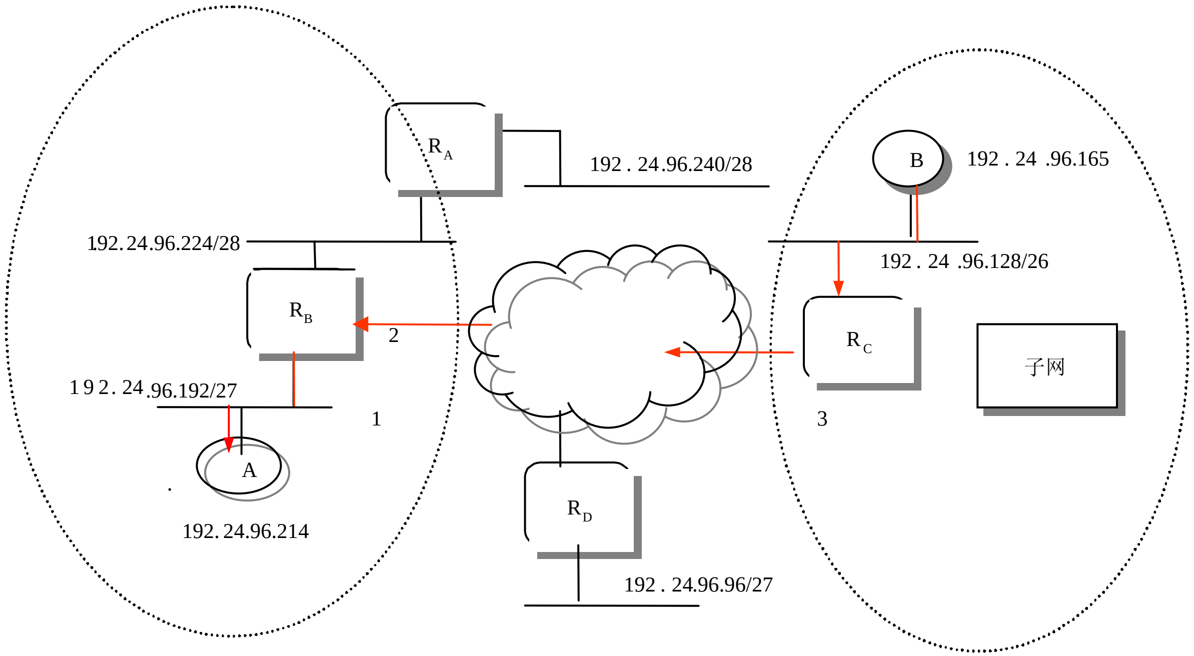
Generation mobile communication system will be the so-called mobile internet.

It is a good approach to support horizontal and vertical handoff by providing mobility in network layer of TCP/IP

http://www.ntpo.org.tw/b3g_2.htm.

❑Mobility is necessary

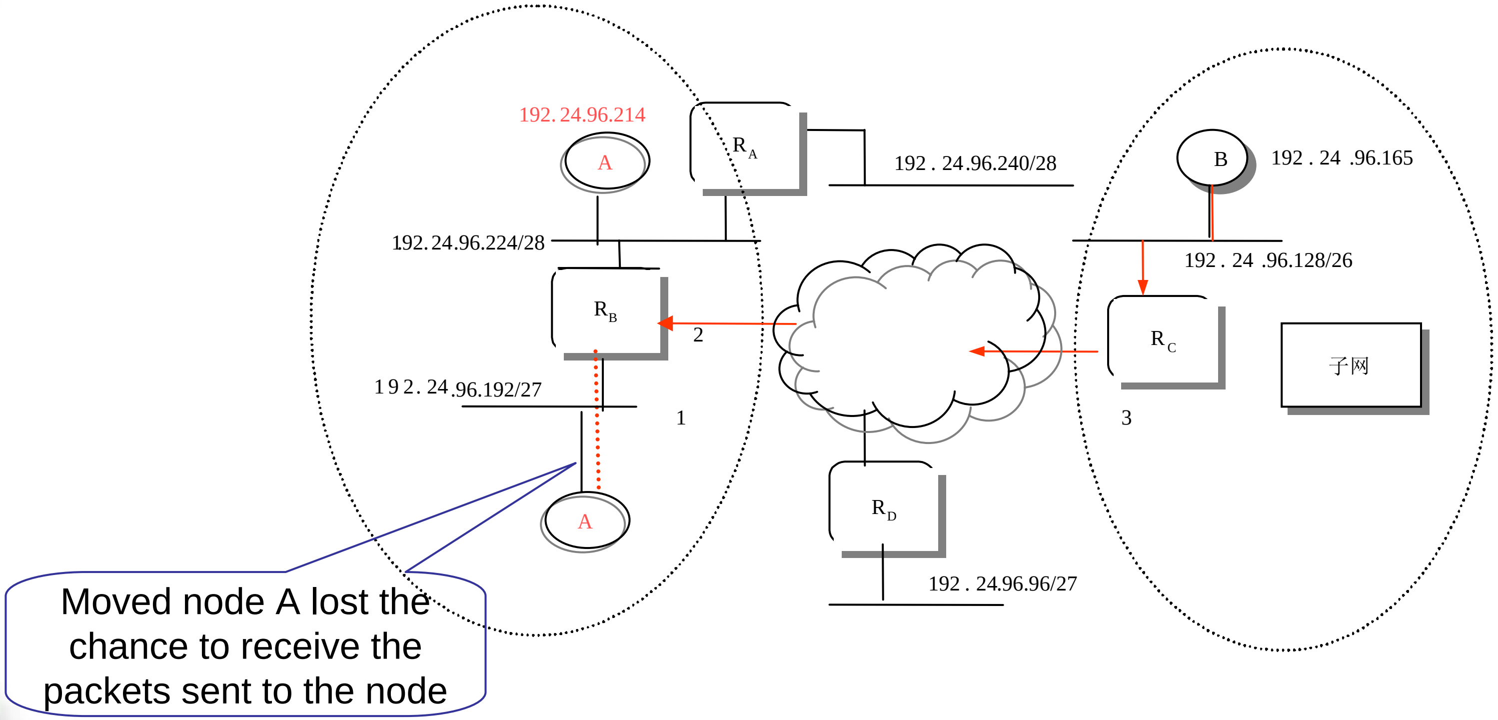
- However, the original design of Internet aims at fixed network
  - –Longest-prefix match based routing
  - –IP address + Port number based identifier of communication



A scenarios of routing packet in fixed internet

❑Mobility is necessary

- The original design of Internet aims at fixed network
  - –Longest-prefix match based routing
  - –IP address + Port number based identifier of communication



A scenarios of routing packet when A moved

❑Overview of IPv6

- History, some IPng proposals
  - TUBA (TCP & UDP with bigger address), RFC 1347
  - IPv7, proposed by Robert Ullmann in 1992
  - CATNIP (Common architecture for Internet), RFC 1707
  - IP in IP, 1992
  - IPAE (IP address Encapsulation), 1993
  - SIP (Simple IP), by Steve Deering
  - PIP (Paul's Internet Protocol), by Paul Francis
  - SIPP (Simple IP Plus), RFC 1710
  - In 1994, IETF proposed the first version of IPv6 based SIPP, RFC1752
  - Obsoleted by RFC1884, by RFC2373
- Characters
  - Tremendous IP address, 128 bits length
  - Fixed length of IP header
  - Embedded IPsec, and Mobility management
  - ……

❑Overview of Mobile IPv6

- **Allow mobility of** end-systems **without communication disruption:**
  - mobile node **MN** is identified by its **home address** (address on the home link)
  - a new temporary address (**care-of address**) is allocated to **MN** on each visited foreign link and is used for routing.
  - MN is associated with a **Home Agent HA** (a router on the home link)

Mobile-IPv6 is a work in progress in the IETF, offering support for IPv6 *mobile nodes*. Every IPv6 node is required to implement Mobile-IPv6, which means that mobility is ought to be widely supported in IPv6.

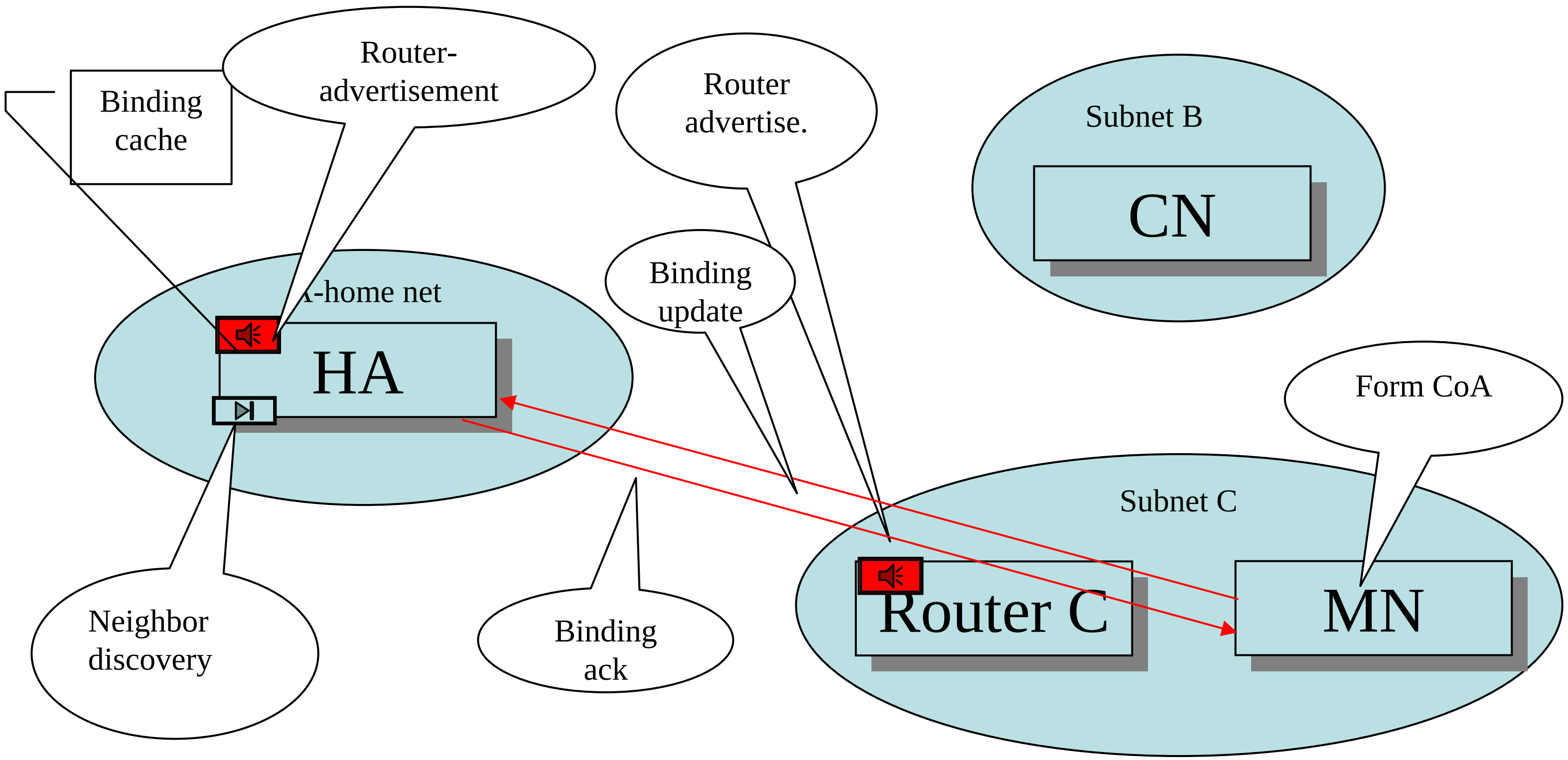
❑Overview of Mobile IPv6

- **Working Group** Mobile IP **at the** IETF
  - MIPv4
  - MIPv6
  - MIPSHOP, MIPv6 Signaling and Handoff Optimization
    - FMIPv6, Fast Handover for MIPv6
    - HMIPv6, Hierarchical MIPv6
  - NEMO, Network Mobility
- Some RFC
  - MIPv4: RFC2002, 2003, 2004, 2005, 2006, 3344
  - MIPv6: RFC 3775

❑Overview of Mobile IPv6

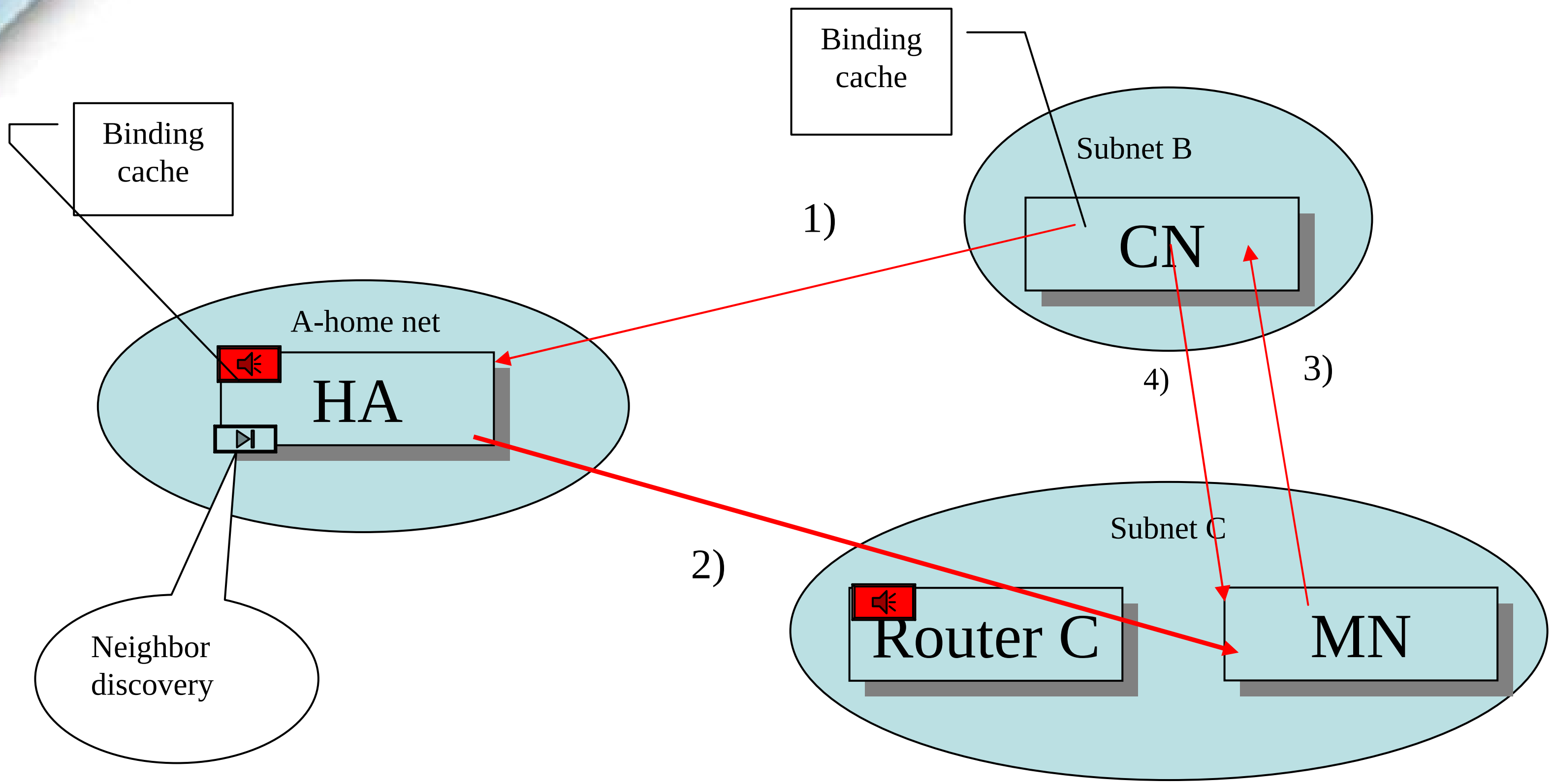
- Plentiful IP addresses
  - 128 bits address space
- Plug and Play via
  - Router discovery
  - Auto-configuration of IP address
- Multiple Care-of-Address and soft handoff
- Routing optimizing via
  - Routing Header and IP Tunnel
  - Destination Option Header
- Security support
  - IPsec

- Basic protocol steps of location management



MN obtains care-of address from a router on the foreign link
MN registers its current care-of address with its home agent HA.

- # Routing packets



- First packets
  - CN sends packets to the HoA
  - HA intercepts, encapsulates, and redirects packets to CoA
  - MN decapsulates packets

- Following packets
  - MN sends its CoA to CN.
  - CN sends packets directly to the CoA using a IPv6 Routing Extension Header.

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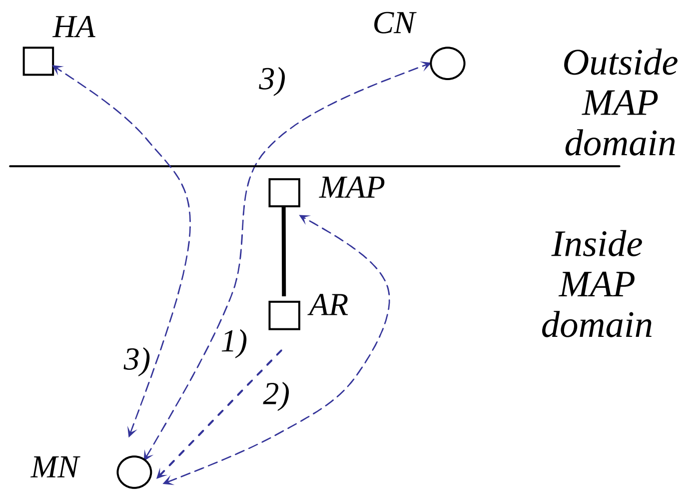
❑Incentive of HMIPv6

- IETF draft
  - Draft-ietf-mobileip-hmipv6-xx, Hierarchical Mobile IPv6 mobility management
- Two key target of research HMIPv6
  - Reduces the number of location registration messages in backbone network
    - through configuring some routers residing in a network visited by a mobile node to be Mobile Anchor Points (MAP), which are used by the node as a local Home Agent.
  - Speed handoff to some extent

❑The principle of HMIPv6



HA: Home Agent CN: Correspondent Node MN: Mobile Node
MAP: Mobile Anchor Point AR: Access Router

Figure Location registration procedure of HMIPv6

1) MN inspects router advertisement messages to detect the change of MAP domain, and configures
2) MN requires MAP to set up a binding entity between RCoA and LCoA. (Note that HoA of the MN will replace RCoA in the binding entity when using extended mode.)
3) Then, MN notifies CN and HA to set up binding entities between RCoA and HoA

If the MN changes its current address within a local MAP domain (LCoA), it only needs to register the new address with the MAP

❑The principle of HMIPv6

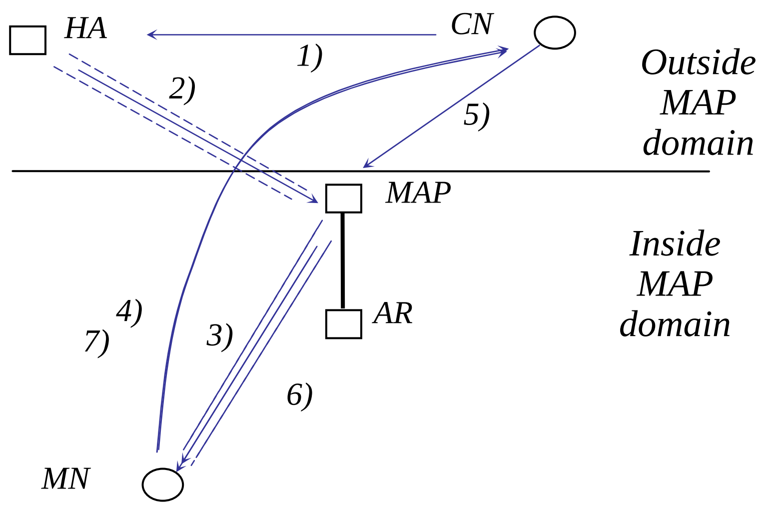
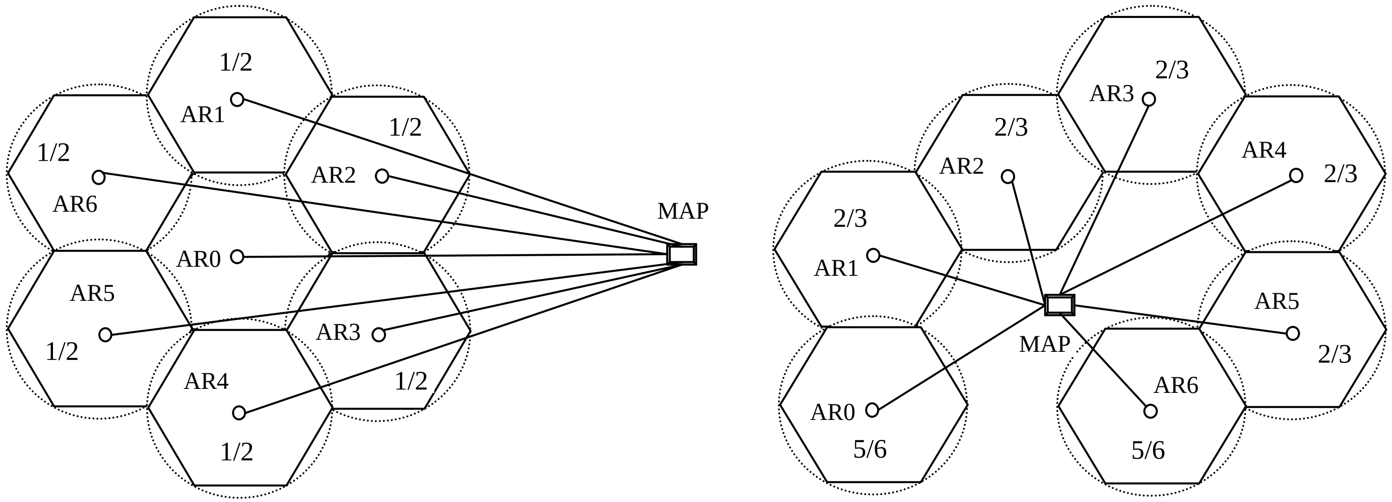


Figure Routing procedure of packets sent from CN

Although the actual processes of sending packets are determined by network configuration, almost all the incoming packets shall be routed to MN by MAP via tunnel.

❑ Reduction of protocol messages



(a) Best case
Closed form

(b) Worst case
Loose line form

$$R_{\min} = 6 * 0.5 \big/ 7 = \frac{3}{7}$$

$$R_{\max} = \left[\frac{2}{3} * (7-2) + 2 * \frac{5}{6} \right] \Big/ 7 = \frac{5}{7}$$

Fig. The relationship of *R* and the topology of MAP

R: the ratio of messages of HMIPv6 to messages of MIPv6 in backbone
The higher *R*, the better the result of HMIPv6 reducing protocol messages in backbone

❑ Reduction of protocol messages

The general function of counting *R based* k_{AR}

$$R_{\max} = \frac{2k_{\mathrm{AR}} + 1}{3k_{\mathrm{AR}}} \qquad R_{\min} = \frac{2x-1}{k_{\mathrm{AR}}} - \frac{1}{3k_{\mathrm{AR}}}\left[\left|\frac{3x^2 - 3x + 0.5 - k_{\mathrm{AR}}}{x-1}\right|\right]^{*}$$

Where

k_{AR} The number of AR corresponding a MAP $\qquad x = \left[\frac{1}{2}\left(1+\sqrt{\frac{4k_{\mathrm{AR}}-1}{3}}\right)\right]^{**}$

Or, when $k_{\mathrm{AR}} > 7$ $\quad R_{\min} = \frac{6p_{\max} + q_{\max} + 4}{3k_{\mathrm{AR}}}$

$$p_{\max} = \max\left\{p \middle| k_{\mathrm{AR}} > 3p(p-1)+1,\ p \in N^{+}\right\}$$

$$q_{\max} = \max\left\{q \middle| \left[k_{\mathrm{AR}} - 3p_{\max}\left(p_{\max}-1\right)-1\right] \ge qp_{\max},\ q \in \{0,1,2,3,4,5\}\right\}$$

- Conclusion:
  - as the k_{AR} increasing, R_{min} decreases, namely, the number of messages outer MAP decreases.
  - However, it doesn't mean that increasing *k*AR is helpful to improve performance of HMIPv6 always
- The passive impactions:
  - Bottleneck in MAP
  - Handoff latency increased when a MAP domain creasing.

* Tsuguo Kato, Ryuichi Takechi, Hideaki Ono. A Study on Mobile IPv6 Based Mobility Management Architecture [J]. Fujitsu Scientific and Technical Journal. 2001, 37(1):65-71.

❑ Handoff latency

$$D_{\text{exc\_reg\_MIPv6}} > D_{\text{exc\_reg\_HMIPv6}}$$

$$\rho_{\text{exc\_reg}} = \frac{L_{\text{MN-HA}} - L_{\text{MN-MAP}}}{L_{\text{MN-HA}}} = \frac{N_{\text{MN-HA}} - N_{\text{MN-MAP}}}{N_{\text{MN-HA}}},$$

Where, $\rho_{\text{exc\_reg}}$ express the ratio of decreased handoff latency via HMIPv6 to MIPv6

When the location of HA fixed, decreasing the path of MN-MAP is necessary to obtain decreased latency, resulting in decreased number of AR, and messages produced outer MAP is increased .

Conclusion:

The size of MAP domain is the key issues

Dynamic and adaptive approach

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❑Incentive

- HMIPv6 reduces the management messages produced in backbone networks, but the management messages increased in a MAP domain as a cost
- As the same time, MAP transfers captured packets to MN via new encapsulation, so the load in the MAP domain is increased in result.
- The target of AMMS is to search a balance to determine when using HMIPv6 could obtain a more reasonable efficiency.

❑Modeling network cost in HMIPv6

- We denote cost as the two parameters
  - *bandwidth consumption*
    - related with intensity of data flow
  - *transfer cost*
    - related with number of data flow and length of routing path

❑Modeling network cost in HMIPv6

To simply analysis, only the situation with a single MAP in a hierarchical domain is taken into account in the queue model. It is assumed that MN doesn't use reverse tunnel to sent packets and only handoff inside the MAP domain is taken into account.

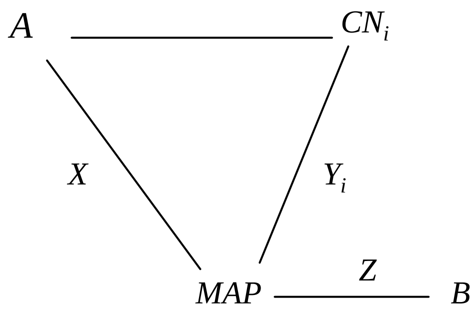


Figure 3. Model of network cost

Shown as Figure 3, B is a mobile node, whose home agent is A.

Random variables:

X----- the network cost per byte of HA-MAP
Y_i----- the network cost per byte of CN-MAP
Z----- the network cost per byte of MAP-MN
D_{HA}----- the number of bytes of messages exchanged between B and A when performing a location registration
D_{CN}----- the number of bytes of messages exchanged between B and CN_i when performing a location registration
D_{MAP} ----- the number of bytes of messages exchanged between B and CN_i when Random
D_{TUN}-----the number of bytes added to a packet by a MAP when forwarding the packet to B via tunnel.

Symbol m means the number of correspondent nodes communicating with node B .

Home agent, A, and CN*i* obey independent Poisson process with mean rate of λ_0 and λ_i packets per second respectively to send packets.

❑Modeling network cost in HMIPv6
(transfer cost)

Random processes:
C_1-----the decreased average transfer cost for delivering location registration messages, compared with MIPv6 when using HMIPv6
C_2-----the increased average transfer cost inside the MAP domain for delivering incoming packets via tunnel in the MAP.
C_3-----the increased average transfer cost inside the MAP domain for delivering location registration messages, compared with MIPv6 when using HMIPv6.

Their average intensity can be calculated as:

$$\mathrm{E}(C_1) = \mu\,\mathrm{E}(D_{\mathrm{HA}})\mathrm{E}(X) + \sum_{i=1}^{m} \mu\,\mathrm{E}(D_{\mathrm{CN}})\mathrm{E}(Y_i) \quad (1)$$

$$\mathrm{E}(C_2) = \sum_{i=0}^{m} \lambda_i\,\mathrm{E}(D_{\mathrm{TUN}})\mathrm{E}(Z) \quad (2)$$

$$\mathrm{E}(C_3) = \mu[\mathrm{E}(D_{\mathrm{MAP}}) - \mathrm{E}(D_{\mathrm{HA}}) - m\,\mathrm{E}(D_{\mathrm{CN}})]\mathrm{E}(Z) \quad (3)$$

❑Modeling network cost in HMIPv6
(bandwidth consumption)

Random processes:
B_1-----the decreased traffic in the unit of byte in backbone network when using HMIPv6
B_2-----the increased traffic in the unit of byte in the MAP domain because of tunnel encapsulation
B_3-----the increased traffic in the unit of byte in the MAP domain for delivering location registrations messages when using HMIPv6

Their average intensity can be calculated as:

The average saved bandwidth outside the domain: $$\mathrm{E}(B_1) = \mu\mathrm{E}(D_{\mathrm{HA}}) + m\mu\mathrm{E}(D_{\mathrm{CN}}) \quad (4)$$

the average consumed bandwidth increased by tunnel encapsulation inside the domain : $$\mathrm{E}(B_2) = \sum_{i=0}^{m} \lambda_i \mathrm{E}(D_{\mathrm{TUN}}) \quad (5)$$

the average consumed bandwidth increased by these messages inside the domain : $$\mathrm{E}(B_3) = \mu\mathrm{E}(D_{\mathrm{MAP}}) - \mu\mathrm{E}(D_{\mathrm{HA}}) - m\mu\mathrm{E}(D_{\mathrm{CN}}) \quad (6)$$

❑Modeling network cost in HMIPv6

- Conclusion
  - One of the important aims in designing HMIPv6 is to increase E(C1) and E(B1)
  - However, E(C2), E(C3), E(B2) and E(B3) are produced at the same time as side effect.
  - the performance improvement on bandwidth consumption and transfer cost of backbone network is at the expense of the increase of cost inside hierarchical domain.
  - Since wireless is the main method used in access network in HMIPv6, decreasing bandwidth consumption and transfer cost inside hierarchy domain is also important.
  - HMIPv6 is not successful sometimes to decrease the total cost on the viewpoint of the entire network resources.
  - For integrated optimization of cost, a mobile node should select a suitable mobility management mechanism intelligently according working parameters
  - We name the new approach **adaptive mobility management scheme (AMMS).**

❑Adaptive mobility management scheme

The judgment rules of AMMS, where cost and bandwidth consumption are taken into account respectively:

- **The conditions which should be fulfilled when using HMIPv6 on the viewpoint of total transfer cost is given by :** $E(C_1) >> \frac{E(C_2)+E(C_3)}{k_1}$
- **The conditions which should be fulfilled when using HMIPv6 on the viewpoint of total bandwidth consumption is given by :** $E(B_1) >> \frac{E(B_2)+E(B_3)}{k_2}$

Where, *k*1 and *k*2 symbolize the convert ratio of transfer cost and network bandwidth from outside MAP domain to inside MAP domain respectively.

The equivalent judgment rule when only considering transfer cost: $\frac{\mu}{\lambda} > \delta_1$ (7)

The equivalent judgment rule when only considering bandwidth consumption: $\frac{\mu}{\lambda} > \delta_2$ (8)

Where,

$$\delta_1 = \frac{\mathrm{E}(D_{\mathrm{TUN}})\mathrm{E}(Z)}{\left\{\mathrm{E}(D_{HA})[k_1\mathrm{E}(X)+\mathrm{E}(Z)]+\mathrm{E}(D_{\mathrm{CN}})\left[m\mathrm{E}(Z)+k_1\sum_{i=1}^{m}\mathrm{E}(Y_i)\right]-\mathrm{E}(D_{\mathrm{MAP}})\mathrm{E}(Z)\right\}}$$

$$\delta_2 = \frac{\mathrm{E}(D_{\mathrm{TUN}})}{[(k_2+1)\mathrm{E}(D_{\mathrm{HA}})+(k_2+1)m\,\mathrm{E}(D_{\mathrm{CN}})-\mathrm{E}(D_{\mathrm{MAP}})]}$$

$$\lambda = \sum_{i=0}^{m}\lambda_i$$

❑Adaptive mobility management scheme

The integrated judgment rules of AMMS

The integrated rule used to determine when HMIPv6 is adopted preferably is written as ,

$$R_{PH} < \delta_{max}$$

The integrated rule used to determine when HMIPv6 is not suitable to be adopted is written as ,

$$R_{PH} > \delta_{min}$$

Where, δ_{max}=max(δ_1, δ_2) and δ_{min}=min(δ_1, δ_2),
$R_{PH} = \lambda / \mu$, namely Packet to Mobility Ratio

❑Adaptive mobility management scheme

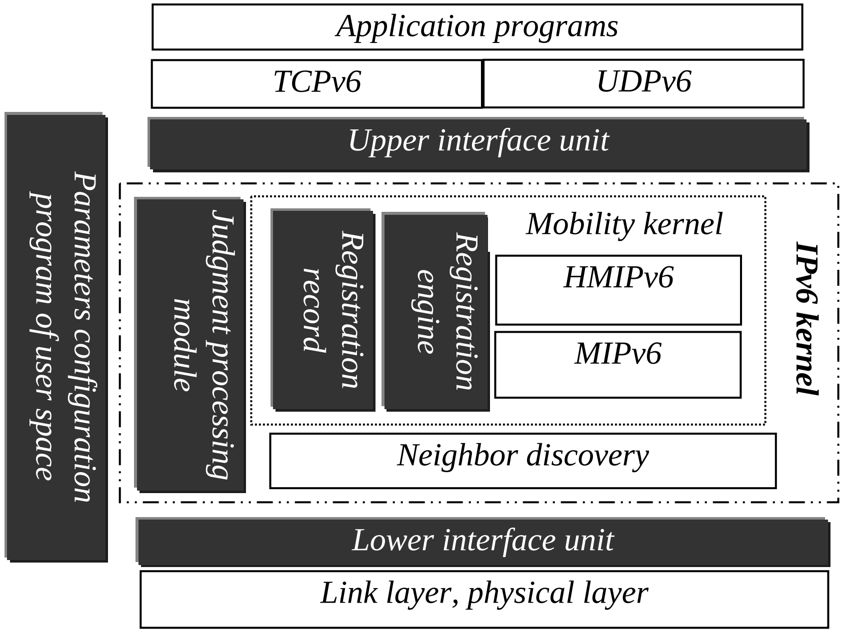


Fig. implementation skeleton diagram of AMMS

Judgment processing module performs the judge rule when need and set the items of *registration record*.

Registration record composed by some data structures

Registration engine checks whether HMIPv6 is supported by the network and exchanges suitable location registration messages according to the item *type* in *registration record*.

❑Adaptive mobility management scheme

➢Simulation

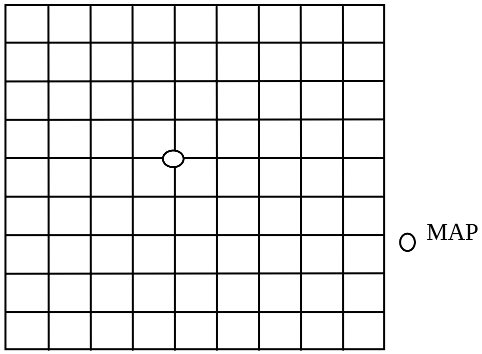


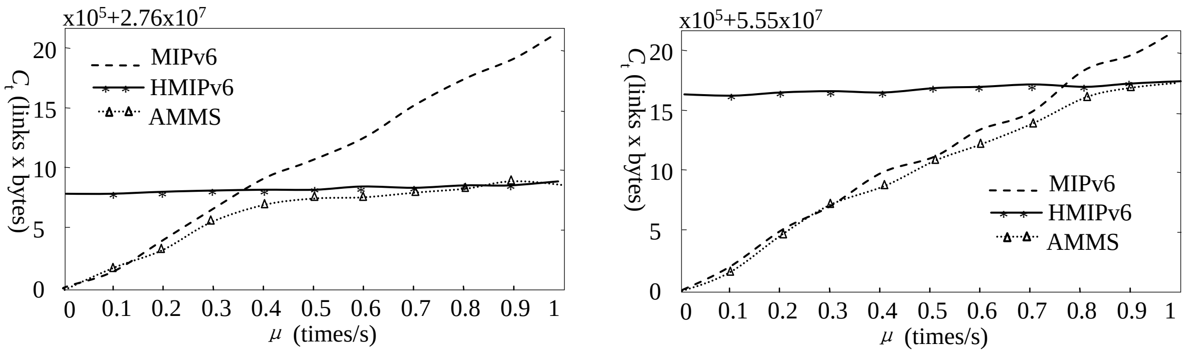
Figure . The 10x10 mesh network

Parame.	Description	Value
E(D_{HA})	The average traffic amount of one registration between MN and HA	150 bytes
E(D_{CN})	The average traffic amount of one registration between MN and CN	150 bytes
E(D_{MAP})	The average traffic amount of one registration between MN and MAP	150 bytes
E(D_{TUN})	The average overhead added by MAP for tunneling a packet	40 bytes
P_1	Path Maximum Transfer Unit	1500 bytes
P_2	The number of byte of a packet sent from CN or HA to MN.	1000 bytes
μ	The handoff rate of MN per ten seconds	0.1,0.2,…1 times/s
λ	The total packet rate sent from all CN and HA to MN	100,200packet/s
m	The number of CN	9
T	The duration to execute a test	200s
k_1	The convert ratio of transfer cost between outside and inside the MAP domain.	1
k_2	The convert ratio of bandwidth consumption between outside and inside the MAP domain.	10

Based a 10*10 mesh network, the network topology in our simulation is randomly constructed at each time. the location of MAP is fixed at (5,5). HA and routers of CN are selected from cross-points except MAP.

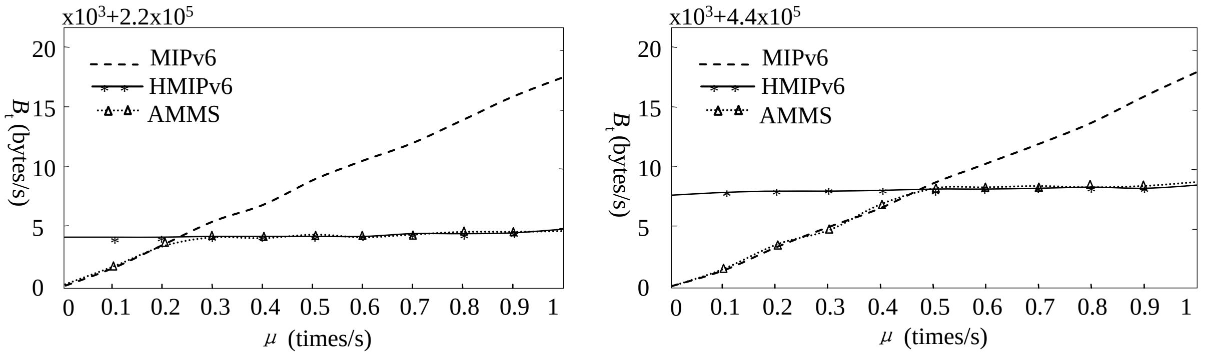
❑Adaptive mobility management scheme

➢Simulation



(a) λ=100 (b) λ=200

Figure 7. Simulation of total transfer cost



(a) λ =100 (b) λ =200

Figure 8. Simulation of total bandwidth consumption

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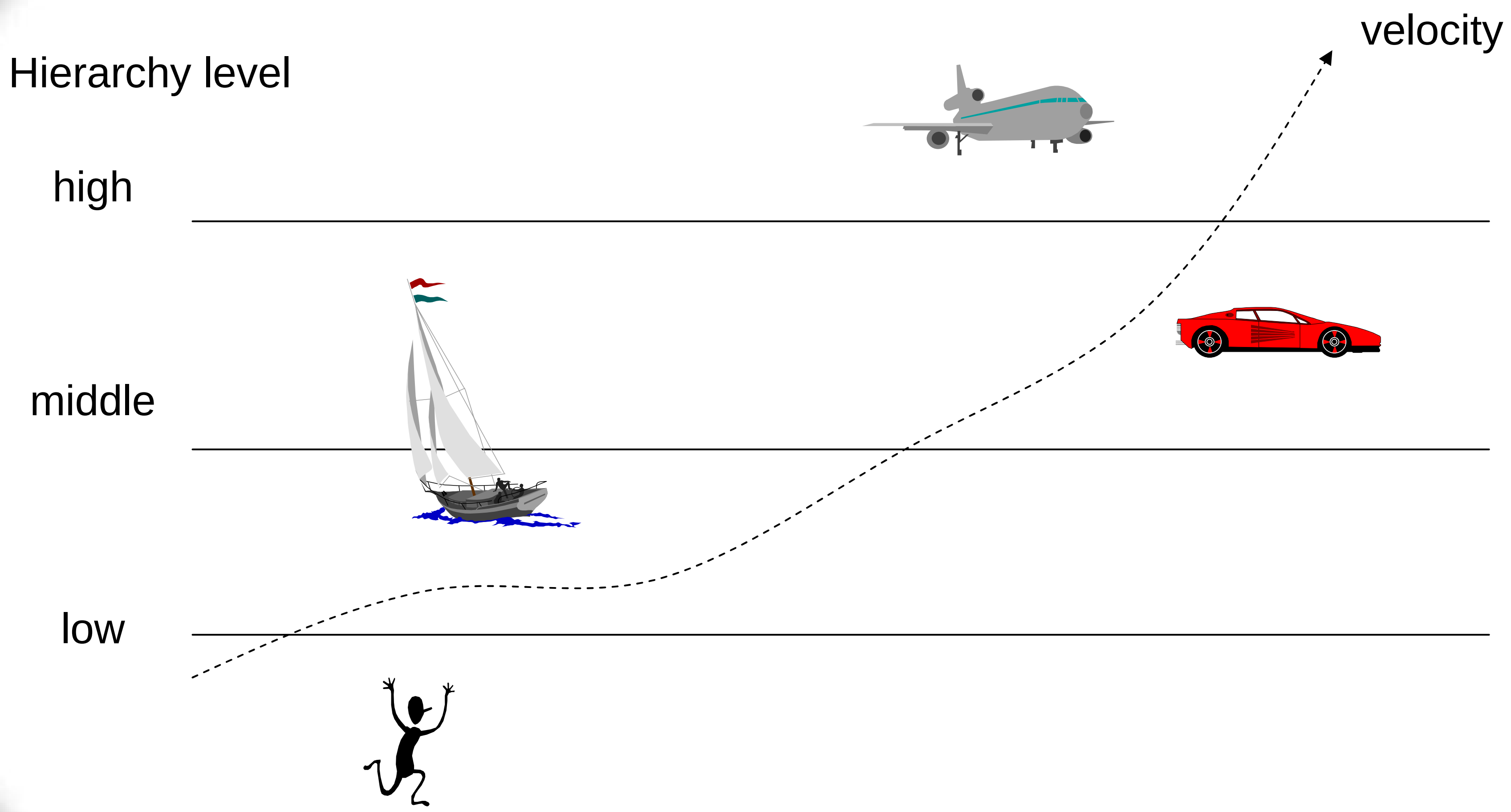
❑Incentive

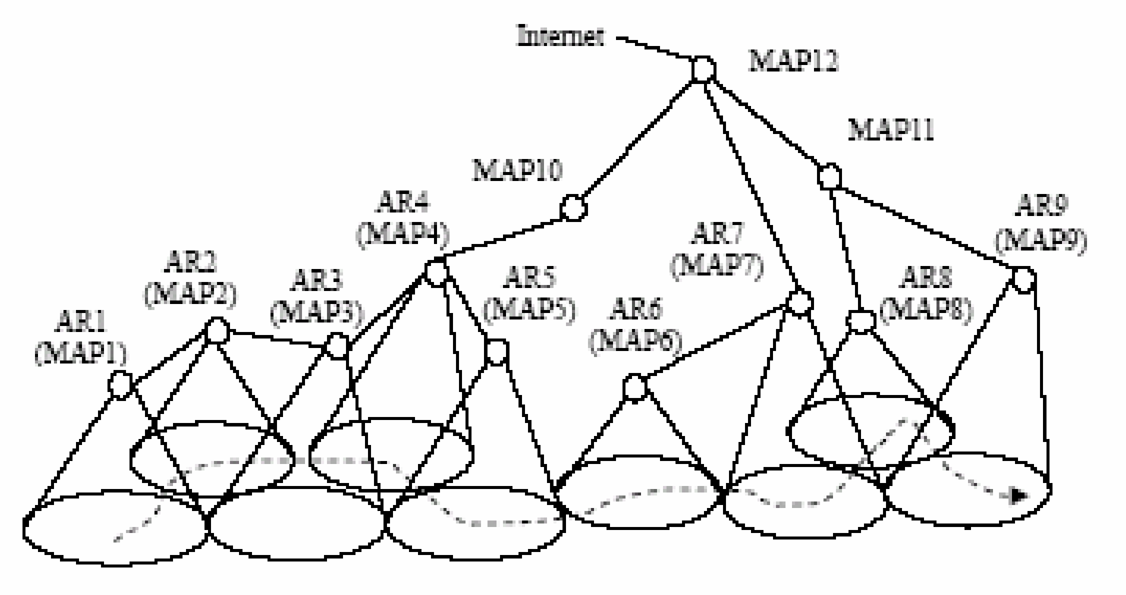
- Bottleneck produced for single MAP
- Diversity of services and moment behaviors
  - Services
    - voice, data, video
    - Real-time, unreal-time
    - Narrow bandwidth & broad bandwidth
  - Movement behaviors
    - Low speed
    - High speed
  - It is not reasonable to adopt a fixed hierarchy for all kinds of devices and users

- The target is to establish Multi-level hierarchy efficiently based on AMMS, and adaptive selection algorithm is needed also.

❑Incentive



❑Extending AMMS with Multi-MAP



The targets in detail :

•Applied in general topology, including Tree with average length, and line style

•Adaptively select hierarchy level based velocity and data traffic

❑Extending AMMS with Multi-MAP

Basic Ideas

➢ *flooding,* a new field in MAP option, expresses the mode of delivering MAP option

0, top to bottom

1, flooding MAP option or other modes

Noted that MAP with *flooding*=1 should be configured with a hop limitation

the number of the MAP with *flooding=0* express the hierarchy level

➢ Adjust the mode of transfer MAP option

MAP with *flooding*=0 checks the MAP option with *flooding*=1 , if from its parent node, modify the field of option, *flooding*=0, else block the option

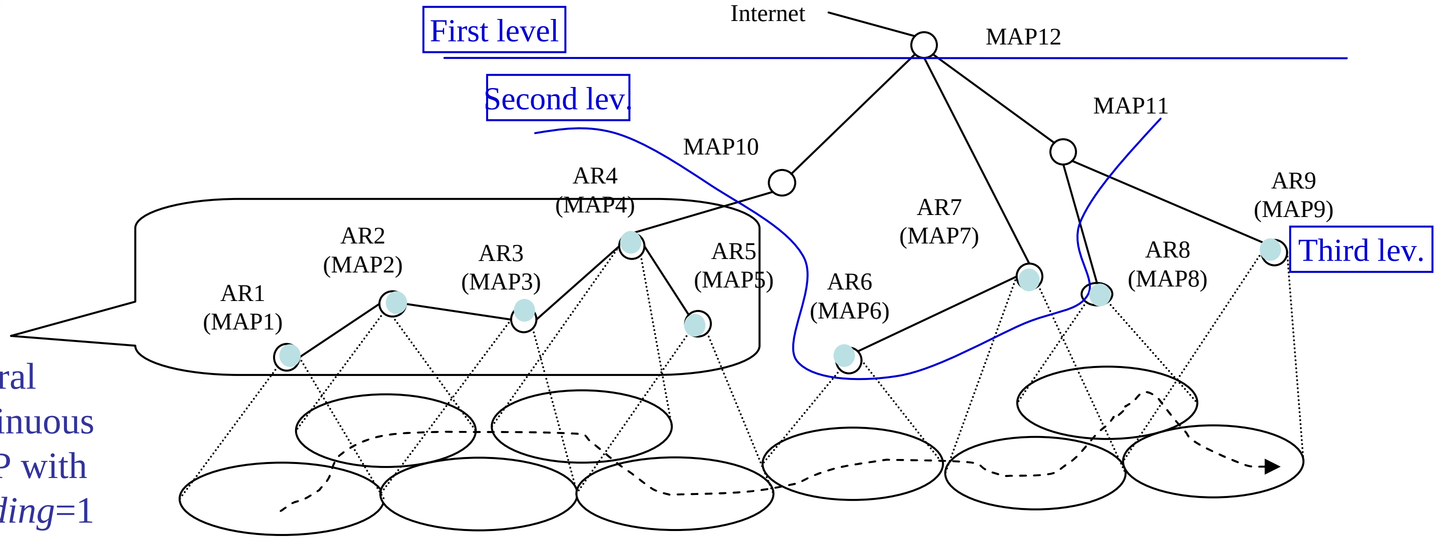
MAP with *flooding*=1 relays all received MAP options, and checks the MAP option with *flooding*=1 to ensure less than the hop limitation.

when transferring MAP option with *flooding*=0 among MAP with *flooding*=1, the hop record should not be increased. Namely, several continuous MAP with *flooding*=1 can be compressed as a hierarchy level.

➢ Adaptive algorithm of selecting hierarchy level

❑Extending AMMS with Multi-MAP

Multi-MAP could be hierarchized automatically according to the above design



several continuous MAP with *flooding*=1 can be compressed as a hierarchy level.

Received MAP option and the value of some fields

经过的 AR	MAP 标识	属性 *flooding*	距离	所属分层等级
AR4	MAP2	1	2	3
	MAP3	1	1	3
	MAP4	1	0	3
	MAP5	1	1	3
	MAP10	0	1	2
	MAP12	0	2	1
AR6	MAP6	1	0	2**
	MAP7	1	1	2
	MAP12	0	1*	1
AR8	MAP12	0	2	1
	MAP11	0	1	2
	MAP8	1	0	3

❑Extending AMMS with Multi-MAP

➢ Adaptive algorithm of selecting hierarchy level

Setp1, counting $j = \min\left\{i \middle| R_{ph\_i} \le R_{ph}, \quad i \in N^{+} 且 i \le n\right\}$ if the current MAP's *flooding=1*, goto step 2, else goto step 4;

Step2, if MN is in the coverage of the current MAP, and $j \ge k$,then the MAP is selected and goto step 7, else goto step3;

Step3, if MN is in the coverage of the current MAP, and $j < k$,then the MAP of upper level is selected, goto step 7, else goto step 4;

Step4, if a MAP with flooding-1 can be received by MN, and a MAP with flooding=1 can be found in the service domain of the nearest MAP (flooding=1) , goto step 5, else goto step 6;

Setp5, if *j* is not less than the hierarchy level of the nearest MAP, then the MAP is selected, else the upper MAP is selected, goto step7 ;

Step6, if MN owns a MAP with flooding=0 in the *j* hierarchy level, then the MAP is selected, else the nearest MAP is selected, goto step 7;

Step 7, register to the selected MAP.

❑Extending AMMS with Multi-MAP

- Flexible topology
  - Tree, flat
  - Compressing MAP chains, via *flooding*
  - the number of the MAP with *flooding=0* express the hierarchy level
- The algorithm of selecting MAP is based data traffic intensity and velocity, which could be obtained in a easy way.
  - R_{PH}
- Load balance via adaptive algorithm
  - Only nodes with little R_{PH} could select the upper MAP.
  - So, the bottleneck could be avoided in some extent.

Outline

- Background of IPv6 and Mobile IP
- Performance Evaluation of Hierarchical Mobile IPv6
- Adaptive Mobility Management Scheme (AMMS)
- Dynamic Hierarchy by Extending AMMS with Multi-MAP
- Further thinking

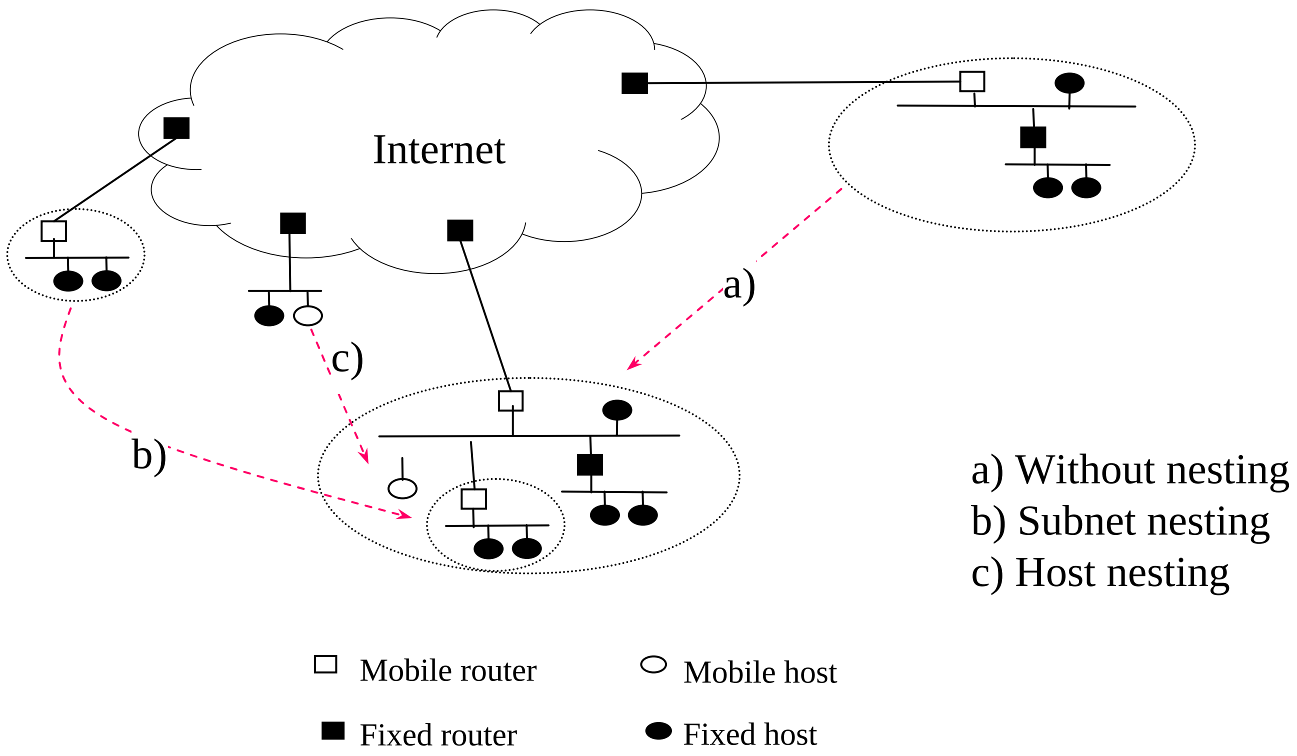
- Some traditional research topics could be rethought in the new environment of Mobile IPv6
  - QoS, Routing & switch, Security….
- Network Mobility
- Trustworthy mobile and wireless networks
- Simulation based on STARBED

❑Networks Mobility

- NEMO, Network mobility
  - Concerned with managing the mobility of an entire network that is changing its point of attachment to the Internet and thus its reachability in the Internet topology.
  - If network mobility is not explicitly supported by some mechanisms, existing sessions break and connectivity to the global Internet is lost

- Some application scenarios
  - Train equipped with WLAN providing the service for passengers
  - Moving Car equipped sensors transfer data to control center
  - ……

❑Networks Mobility



Three basic mobile modes in NEMO

❑Networks Mobility

- Some challenges
  - More users
    - A moving network may comprise hundreds nodes, X
    - A node in a moving networks may own dozens corresponding nodes, Y
    - The total corresponding nodes of a moving network, sometimes
      - X *Y > 1,000
  - More complex moving behaviors
    - Entities
      - Fixed host, fixed router
      - Moving host, moving router
    - Moving behaviors
      - Three basic mobile modes
      - hybrid modes
  - More serious security
    - Exchanging mobility management signaling trustworthily
    - Location privacy
  - More heavy cost of mobility management
    - Too many corresponding nodes need to be informed new location

❑Networks Mobility

Some interesting topics

- Modeling and Analysis of Network Mobility
  - Modelling, Analysis and Simulation of Mobile Router
  - Protocols for Route Optimization
  - Mobility Issues Inside a Mobile Network
  - Mobile IPv6 Extensions for Route Optimization
  - Nested mobile networks
  - Multihomed mobile networks
  - Operational issues to deploy mobile networks
  - Auto-configuration for mobile networks
  - Mobile Router Support on Cellular Phone Platforms
- Services in the Networks that Move
  - Service advertisement and discovery protocols in networks that move
  - Specifications and models of services for network mobility
  - Encryption and authentication in service access for network mobility
- Security issues in Network Mobility
  - Security Analysis of Present Network Mobility Support Protocols
  - Applications of AAA and EAP to Network Mobility
  - Interaction with security-enhanced modules in other layers (vertically) or other middle boxes (horizontally)

❑Trustworthy Mobile and Wireless Networks

- No absolute security
  - Traditional concept means
    - yes, when attacks fail
    - No, when attacks succeed
  - Security is a target, but difficulty to measure
- Network environment & human society
  - Man-made system
  - Work for human society
  - Some similarities exist
- Network behaviors & human activities
  - Behavior analysis
  - Trustworthiness
    - Multi-level
    - Based on behavior
  - Trust relationship
    - Description
    - Computing

❑Trustworthy Mobile and Wireless Networks

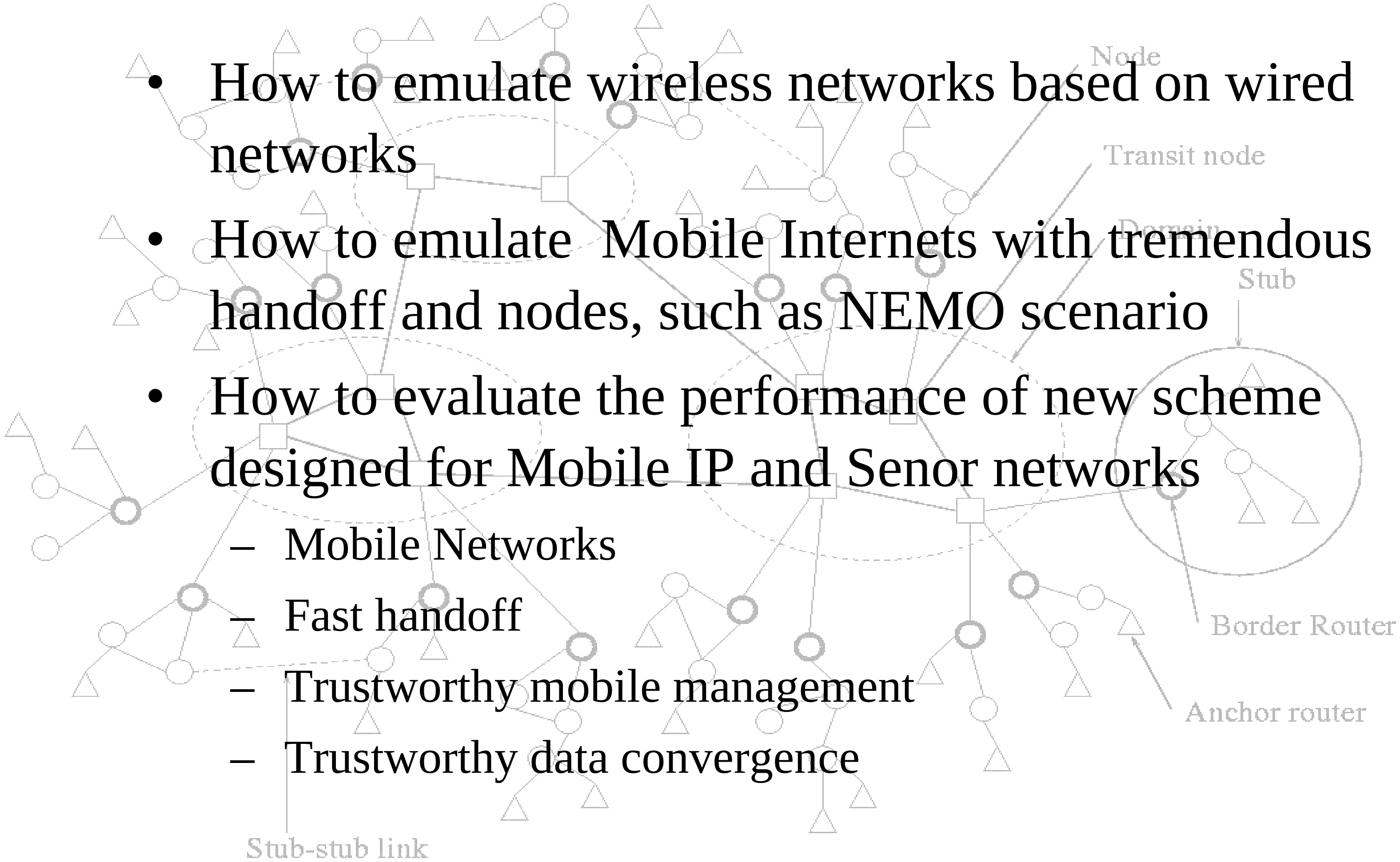
- Although the objectives of both mobile wireless networks and traditional fixed networks are the same, such as availability, confidentiality, integrity. But the security issues involved in mobile wireless networks are quite different.
  - [Highly reliable trust establishment scheme in ad hoc networks]
- Trustworthiness challenges in mobile & wireless networks
  - Variable topology, hard to monitor behaviors directly
  - No central control mechanism in ad hoc
  - Limited computing resources
  - Open communication media
  - More complex relationship between corresponding nodes, such as
    - More nodes participate in MIP: HA, CN, MN, etc
- Research on Trustworthy mobile & wireless networks
  - Trustworthy mobility management in MIP
  - Trustworthy ad hoc
  - Trustworthy sensor networks
  - ….

❑Simulation based on STARBED

- STARBED
  - http://www.starbed.org
  - Internet Experiments on Actual Node-based Testbed
    - 512 PCs, 10 VMWARE each PC,

❑Simulation based on STARBED

- How to emulate wireless networks based on wired networks
- How to emulate Mobile Internets with tremendous handoff and nodes, such as NEMO scenario
- How to evaluate the performance of new scheme designed for Mobile IP and Senor networks
  - Mobile Networks
  - Fast handoff
  - Trustworthy mobile management
  - Trustworthy data convergence



Thank you!