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Title: **Naming and addressing issues for Future Network**

Source: **SC 6/WG 7 (June 2009, Tokyo meeting)**

SC 6/WG7 reviewed the contributions from China and Korea on Naming and Addressing Schemes (NAS) for Future Networks. SC 6/WG7 recognized NAS is important and urgent field of Future Network standardization. SC 6WG7 decided to have a study period for possible new project on NAS. SC 6/WG7 agreed to circulate those contributions to SC6 national bodies for review, and to solicit comments on the work scope and directions of Future Network Naming and Addressing Schemes (FN-NAS) to be discussed in the next London meeting, 2010.

<Attachment 1> Future Network Naming and Addressing Schemes: Problem Statement and Design Goals

<Attachment 1> A new Geographical Addressing Scheme

<Attachment 1>

Future Network Naming and Addressing Schemes: Problem Statement and Design Goals

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1．Summary

This technical report is prepared by Chinese experts in May 2009 for ISO/IEC JTC1 SC6's Future Network meeting in Tokyo, Japan, June 2009. It reviews the structural limitations of existing network in the area of addressing and naming schemes, discusses how these limitations cause inconveniences and inefficiencies in network communications. In light of the design goals of Future Networks, the report discusses why new naming and addressing schemes are needed and what kind of functionalities are required. The report also provides suggestions on the next step.

2．Background

In the Xi'an meeting in April 2007, ISO/IEC JTC1 SC6 decided to initiate work on Future Network, a clean slate design of a new network to face the need beyond 2020.

In October 2007, the first Future Network meeting was held in Paris. Among the 9 presentations submitted to the meeting, only one report covers the issue of a new naming and addressing architecture for the new networks. [1]

During the comment period after the Paris meeting, China National Body submitted comments which pointed out that naming and addressing are the core research areas for the new network and works on these issues should start earlier than other non-core areas. The document also indicated that China's IPV9 project had done extensive research in this area.[2]

During the Geneva meeting in April 2008, the National Body of Korea submitted a contribution entitled "A Position-based geographical addressing scheme".[3] This is the second document in SC6 regarding addressing and naming after China's IPV9 presentation.

SC6 recognized the importance of naming and addressing issue and encouraged Chinese experts to prepare a detailed report on the concept of a new naming and addressing scheme for Future Network in future meeting.[4]

3．Objectives of This Study

This report has two objectives: to discuss the importance of a new address and naming scheme for future network and to point out the directions of future research in this area.

This report is more like a feasibility study, rather than presentation of a specific technology. We will focus on the general issues surrounding naming and addressing, such as problems, goals, gaps etc. At this early stage, we will avoid focusing on any specific technology. Nevertheless, some advanced research projects such as China's IPV9 may provide valuable insights or experiences which may inevitably be referred to when we come into specific technical analysis. Without those experiences, we may not be able to find out fully the deficiencies of old naming and addressing schemes and may not be confident about whether Future Network design goals can be met.

4. The Importance of Naming and Addressing Scheme in New Network Designs

Naming and addressing are two closely related core schemes in any network designs.

Naming is a scheme which gives identity to every computer or object connected with the network or the party who is going to send or receive information from the network.

Addressing is a scheme which provides information on the point where the sender or receiver is located in the networks.

Just like the post systems, networks are designed to deliver information from one point to another remote point or from one person to another person. In order to conduct the delivery, the sender must first know the other party's name and secondly he must know where the other party is located. Therefore, a network system must contain the naming and addressing schemes as the most fundamental protocols so that the machines know whom and where to send the information to.

In network designs, naming and addressing are not only essential and indispensable, but also occupy top priority in design time-tables. Only after naming and addressing schemes are set, the whole architecture and other subsystems such as router designs and application services can have a base to start work on.

5. Problems in Existing Naming and Addressing Schemes

In Future Network research, naming and addressing schemes are also essential and indispensable. It is not because the simple fact that a new network needs new scheme, but also because the old naming and addressing schemes have structural limitations and are not fit for future network environment.

5.1 Old Domain name and IP Address Schemes

Current internet networks rely on TCP/IP version 4 and 6 (IPV4 and IPV6) to conduct communication and connection. Every machine has a unique identity-bound IP address, so to distinguish the millions of users and computers from each other on the networks. The network adopted a unique and standard address format, giving a unique IP address to every network connected sub-network or machine, so that it can recognize and distinguish them.

In order to ensure the uniqueness of IP addresses of every computer on the network, a registration scheme is adopted in older network designs. User has to apply for registration from designated central registry administration agency. The agency considers the applicants size and future development outlook and allocates IP addresses.

IPV4 and IPV6 utilize separate schemes for naming and addressing. IP addresses are designed for machines to find destinations of information delivery. Domain names are mainly composed of characters whose combination can help people to identify and memorize names of the location. Every domain name has one dedicated IP address to match. Domain names make it easier for people to visit locations on the network. The combination of IP addresses, domain names, allocation, registration and management systems forms the core mechanism of current communication networks.

5.2 Historical limitations of old naming and addressing system

When evaluate the current IP naming and addressing schemes, we have to take two perspectives: one is historical and the other futuristic.

In historical perspective, we have to give current IP naming and addressing schemes the credit for what they have achieved. They become the base for world-wide networks that connect billions of people across the world.

In futuristic perspective, we have to realistically acknowledge that current IP naming and addressing schemes, because of their inherent weaknesses, is incapable of doing what we would ask them to do. We have to search for alternatives.

Current IP naming and addressing schemes rely on a design concept which was formed about 40 years ago and is therefore outdated.

IPV4 naming and addressing schemes were originated in the 1960s and 70s. At that time, computer communications has limited usage. The designers never envisioned how fast and how broadly the networks have developed and expanded worldwide. There are millions of computers and billions of users on the network everyday. There is a conflict between the limited usage design and unlimited actual usage request. This creates many problems. The shortage of IP addresses was one example of the problems.

Although IPV6 adopted a new addressing scheme, it does not deal with all the problems. The advantage of IPV6 is its expansion of available IP addresses. However, because IPV6 continued an “evolutionary” approach and never intended to do complete structural reshaping, it left many problems untouched.

5.3 Technical limitations of old naming and addressing system

Current naming and addressing schemes have the following major limitations:

5.1 The Old schemes require the Central registration authority, which maintains the control of the key facilities of the Internet. This causes widely concerns of information security among the international community.

5.2 The centralized domain name registration schemes create economic burdens for heavy IP address users or nations.

5.3 IPV4 address resources have limited supplies. By 2010, IPV4 addresses are forecast to be exhausted.

5.4 Routing tables are becoming more and more bulky. It causes problems for management and maintenance and increases router work load.

5.5 Centralized domain name system forms a vertical structure, with multiple bottlenecks which generate or increase heavy network congestion.

5.6 The separation of domain names and IP addresses requires a Domain name to IP Address conversion process. It reduces information delivery speed and causes many burdens.

5.7 IPV4 can only utilize data encryption (IPV6-IPSec), but its addresses cannot be encrypted. It cannot provide address confidentiality.

5.8 IPV4 addresses can only provide “type” addresses, but can not provide “leveled” addresses which are essential for high quality communication applications such as multi-media and real time information transmissions.

5.9 Existing naming and addressing schemes lacks consideration or respect for geographical or national considerations. It creates problems for national government in network management and information security.

5.10 IPV4 name and address schemes do not provide language (such as Chinese, Korean, Japanese, Russian, French, German, etc.) direct routing function, and have to rely on domain name conversion schemes.

5.11 However, current domain name conversion systems do not provide language supports other than English, therefore, it cannot create allow or convert domain names based on other languages such as Chinese, Korean, Japanese, Russian, French, German, Arabian, etc.

5.12 Current domain name conversion system cannot provide all decimal name systems such as telephone number, OID coding, mobile phone number, merchandise code, etc. Those numbers have to be inserted into English domain names for conversion. This complicates a simple process. It reduces data security and wastes network resources.

5.4 The Limitations of IPV6

The major improvements from IPV6 are that it increases the length of IP addresses and expands address resources. However, IPV6 does not make significant changes to other aspects of the IPV4 naming and addressing structure. Therefore, IPV6 carries most of the IPV4 deficiencies in naming and addressing. Furthermore, IPV6 eliminates the geographical concept in addressing scheme. This is not good for management, security and economic efficiency.

6 Gap Analysis

6.1 The need for a Clean Slate Design

From above analysis of the limitations of current IP-based network technologies, we can derive the following views:

- Current IP-based networks have many deficiencies.

- Those deficiencies result from structural designs.
- Problems in current IP-based networks were largely related to flaws in naming and addressing schemes.
- It is impossible to overcome those problems without structural overhaul.
- The evolutionary approaches such as IPV6 are inadequate to fix the problems.
- Future Network's clean slate design principle is justified.
- A clean-slate design must include redesigning the naming and addressing schemes.
- In order to achieve the design goals of Future Network, we have to find out what kind of gaps are there between the goals and current systems.

6.2 Future Network Design Goals

In document 6N13490, SC6 described the design goals of Future Network as including eight aspects: [5]

- Scalability
- Security
- Mobility
- Robustness
- Heterogeneity
- Quality of Service
- Customizability
- Economic incentive

6.3 The Gaps

If we compare section 5 of this document which analyze the technical strengths and weaknesses of current IP naming and address schemes with the design goals of Future network described in Section 6.2, we can clearly see the gaps between the two.

The design goals describe idealistic objectives that Future Network is intended to achieve or perform. They are based on the overall observation or evaluation of the existing IP-based networks. Using the design goals as a base for evaluation, we will find that current IP-based network naming and addressing schemes cannot satisfy the needs of Future Network.

6.3.1. On scalability, the rigid structure of centralized domain registration and hierarchical routing systems in IPV4-IPV6 prevent scalable networks from emerging.

6.3.2. On security, the centralized domain name conversion and exposed IP addresses cause wide security concerns.

6.3.3. On mobility, current domain names and address protocols does not fit well into the future network environment which will have more and more new communication devices or services such as mobile phones, RFID, sensors, etc.

6.3.4. On Quality of Service, the future network should support quality of service (QoS) from user and/or application perspectives. The current

IP-based network naming and addressing schemes needs to give more freedom to users and more rooms of expansion for applications.

6.3.5. On Heterogeneity, current domain names and address is incapable of providing name and address structural support for accommodating the integrated networks.

6.3.6. On Robustness, the centralized domain name conversion and hierarchical network routing structures in current IP-based networks is one of the causes for network congestion.

6.3.7. On Customizability, current naming and addressing schemes has too rigid policies and does not provide flexibility for customized network communications.

6.3.8. On economic incentives, current IP names and address fee systems are too expansive for users. Better designed naming and addressing structures also may produce economic incentives resulting from more security and network efficiency.

7 Design goal for Future Network naming and address scheme

Above discussions not only demonstrate the need for a new naming and addressing scheme for Future Network, but also provide valuable information on what kind of goals we should have when considering and evaluating possible candidates of new naming and addressing schemes.

We believe, an ideal Future Network naming and addressing scheme should strive to achieve the following objectives:

7.1 Clean slate design: the naming and addressing must show a clean slate design. Modifications to the current naming and addressing structures are insufficient to fulfill the ambitious goals of Future Network.

7.2 Horizontal structure. The new naming and addressing scheme must have horizontal structures so that it can provide services that the old vertical structures are unable to do.

7.3 Geographical boundaries in Digital World. The new naming and addressing must consider and respect geographic boundaries, especially the national sovereignty in digital world.

7.4 Address confidentiality. The new naming and addressing schemes should provide room for installing mechanisms aimed at improving address confidentiality.

7.5 Flexibility in domain name management. Users (individuals, institutions or public authorities) should have more freedom and flexibility to create, register and manage domain names.

7.6 Enhanced security. The new naming and addressing schemes should provide better security for information exchange through the networks, but also take into consideration of wider security issues, such as the need to maintain rule and order, public facility, personal safety and national security.

7.7 PTP connections. The new naming and addressing schemes should provide a base for Point to Point (PTP) connections which would bring better services, more efficiency and more security.

7.8 Cultural awareness. The new naming and addressing schemes should take consideration of the special needs of different cultures and provide technical support for multi-cultural network environment.

7.9 Information transmission speed: The new naming and addressing schemes should be able to increase the speed of information distribution in Future Network. The may take new naming mechanisms and new address architectures. They should be able to support ideas such as direct routing (without the need for name-address conversion) or character routing.

7.10 Multi-dimensional structure. FNNAS should consider the concept of multi-dimensional network so that the limitations of current hierarchical structure are resolved. Multi-dimensional structure may include concepts such as grid computing, position based addressing schemes, layered addressing schemes, etc.

7.11 Address availability: FU-NAS should design a new address architecture that would offer truly unlimited resources of addresses to whoever wants them and at an affordable cost.

7.12 Address allocation: FN-NAS should reduce the inequality in current address allocation systems. For example, China which possesses 20 percent of world population should be able to should have enough addresses to satisfy the need of its huge population.

7.13 Reduce Network Congestion. FN-NUS must aim at using the new schemes to help reduce network congestion. There should be clear response to bottlenecks exist in current networks.

7.14 Intelligent networks. FNNAS must have a scheme to support the intelligent networks. The issues of mobility, scalability and reprogramming should be considered.

7.15 Economic benefits. The new naming and addressing schemes should increase efficiency so that users would have less economic burden.

7.16 Integration and harmonization. FNNAS must provide mechanisms to support the integration and harmonization of various kinds of services, applications and networks, so that a network platform is established to support the concept of all-service network.

7.17 Pure decimal world. FN-NAS must have designs for pure decimal network communications so that the new network can provide support to some special applications such as mobile phones, RFID, etc.

7.18 Name and Address integration. Looking into the future, there will for sure be a demand from special applications for integration of name and addresses into one entity, but current IP-based networks always separate the two. FN-NAS must find a way to bridge the gap.

7.19 Room for new applications. FN-NAS must have forward looking mentality and leave rooms for providing naming and addressing support to new applications that would emerge in many years to come.

7.20 Consistency. Although there will be too many aspects to consider, FNNAS must maintain consistency. It must have thorough theoretic research and engineering proof of soundness in concepts. Position based addressing scheme.

7.21 Compatibility and interoperability. Clean slate design does not mean elimination of old facilities. FNNAS will not be bound by old naming and addressing rules, however, we should not mislead to believe that the new future network would have conflict with networks build on old naming and addressing schemes. FNNAS should take into consideration of compatibility and interoperability between old and new future network and show a way how it can be achieved (probably it can be done through engineering works).

7.22 Environment protection. FNNAS should find ways to contribute to the protection of environment. Possible options are NAS designs that could reduce the use of energy in network operation and information processing and transmission.

8 Feasibility

Above requirements are essential to achieve the lofty design goals of Future network. They can be met by one NAS design or by a combination of multiple designs. However, no matter how many designs are offered, a coherent relationship must be established among them. Ideally, one proposal is offered that would be able to address all the issues and provide solutions in a systematic way.

Although the requirements look idealistic, they are not impractical illusions. Chinese experts has conducted research on new naming and addressing schemes for many years and from experiences of projects such as IPV9, we are confident that the requirements can be met. (At this early stage, we are not going to discuss detailed technical information of IPV9 here).

There will be an issue regarding whether SC6 is the proper organization to work on a new naming and addressing scheme. There will be a possible argument that traditionally IP naming and addressing schemes are done in IETF. However, we believe that it is must and proper for SC6 to work on the FNNAS project. Our reasons are:

8.1 SC6 Future Network is a project to redesign a new network that would satisfy the needs of the future. Naming and addressing schemes are essential elements of network design. So the FNNAS is within the scope of SC6.

8.2 Future network is a clean slate design, which requires completely new naming and addressing schemes.

8.3 According to IETF’s mission statement, it is to maintain current internet architecture and take an evolutionary approach to improve the current IP-based networks. [6]

9 Next Step

We hope that after the November meeting, SC6 will recognize the importance of a new naming and addressing scheme for Future Network research and take the following immediate steps to move forward on this subject.

9.1. After the meeting, SC6 Secretariat will send this document to SC6 national bodies and relevant organizations for comment and review. The authors are requested to consider the comments received and provide a comment disposal report to the next SC6 meeting.

9.2. In this meeting, SC6 adopt a resolution to formally start a study period on Future Network Naming and addressing schemes (project code name FN-NAS).

9.3. Chinese experts are encouraged to draft a document on Technical guidelines for Future Network Naming and Addressing Schemes. This document may serve as a directional guidance for FN-NAS research and/or as a base for evaluating technical proposal contributions on NAS. A preliminary report should be presented to the next SC6 work group meeting.

9.4. A call for contribution will be sent to National Bodies and relevant organizations to outline a mid-term road map on FN-NAS.

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[1] ISO/IEC JTC1 SC6 document, 6N13376, “IPV9: The Common Ideal for Human Being”, by Xie Jianping, Shanghai Decimal System Network Information Technology Ltd”.

[2] ISO/IEC JTC1 SC6 document, 6N13488, “National Body of China’s Comments on 6N13422 on Future Network”, Jan 31, 2008.

[3] ISO/IEC JTC1 SC6 document, 6N13495, “National Body of Korea’s contribution to Future Network: A position-based Geographical Addressing Scheme”, 2008-02-04.

[4] ISO/IEC JTC1 SC6 document, 6N13618, “Meeting Report of ISO/IEC JTC 1/SC 6/WG 7 on Future Network,” 2008-04-06.

[5] ISO/IEC JTC1 SC6 document, 6N13490, Design Goals and General Requirements for Future Network.

[6] RFC3935, IETF Mission Statement.

<Attachment 2>

A new Geographic Addressing Scheme

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1. Introduction

Various location-based services which provide various services by using location information of objects have been widely disseminated due to the development of wireless communication infrastructures and wired/wireless Internet. Especially, development of mobile communication technologies makes location-based services more noticeable and more important. In addition, the location-based services have been extending to ubiquitous environment and developers related the services work toward to deploy more global service infrastructure by integrating wireless mobile networks and ubiquitous sensor network (USN). USN is an infrastructure network to realize ubiquitous environment using many ubiquitous sensor nodes(u-sensor node) with sensing, processing, and wireless communication capabilities. U-sensor node can get a location information through GPS or manually.

To provide some location-based services to nodes in global network, a global geographic address scheme which can consistently manage and efficiently process location information for nodes is required. The representation of consistent location information using global location-based scheme helps deploy a common infrastructure integrating various heterogeneous networks. Therefore, the global geographic address scheme is necessary.

This paper defines a new location-based geographic address scheme that describes the location information of nodes. This scheme can be used for the maintenance of nodes and for the LBS system based on USN, and so on.

According to the new location-based geographic address scheme, appropriate geographic routing algorithms and tracking methods of mobility nodes will be introduced.

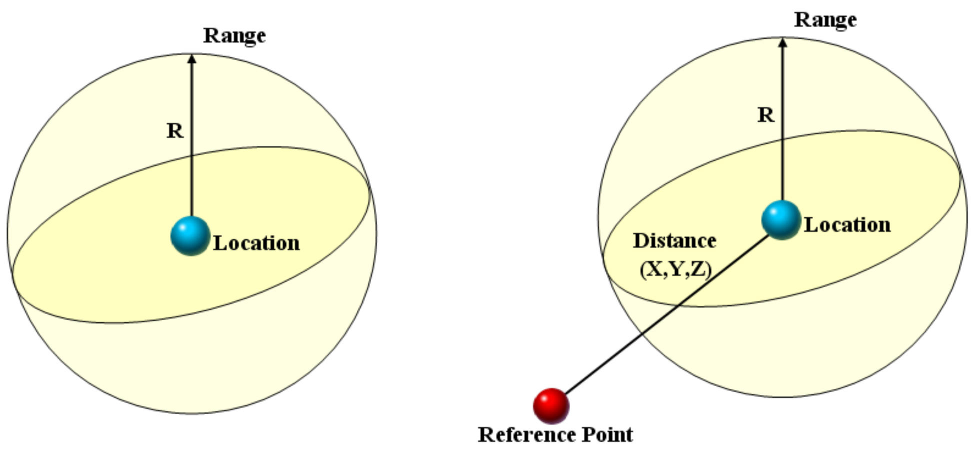
2. Definitions

- Location node: node which can acquire the location information through GPS or manually.
- Non-lotion node: node which can not acquire the location information.
- Absolute address: location node can be represented by latitude, longitude, altit ude and its range from the physically absolute position information.
- Relative address: non-location node can be represented by relative address sch eme based on the reference point recursively.
- Geographic address: geographic address may be either absolute address or rela tive address, representing the location of a node.

3. New Geographic address scheme

A Geographic address scheme defines a representation code of location information to globally present. Location information should be able to be represented according to goal of services. Representation methods of location information is as following

- Absolute/relative location: location information may be represented by absolute location like latitude/longitude/altitude or by relative location using alias like "empire state building", "Golden gate", etc.
- Global/local location: location information may be represented by global or by local location. Global location is absolute location or relative location using area/country code while local location is relative location represented by relati ve distance and range from reference point.
- Reference point or not: location information may be represented by reference point or not. Absolute location information may be represented without refere nce point, while relative location information may be represented by direction and distance from a specific reference point.



(a) Location represented by absolute address (b) Location represented by relative address

Figure1. Locations represented by absolute address and relative address

4. New Geographic address format

This section explains type of address code, definition of fields and necessity of graphical address scheme for node.

4.1 Geographic Address Structure

Code Identifier	Range Info	Distance Info	Location Info

The Geographic Address is composed of code identifier, range information, distance information and location Information fields. That is, Geographic Address is able to describe specific location information and area centering the specific location information by using range information. Also, the address is able to describe relative location away as distance information from specific location.

Detail description of each field is as following.

1) Code Identifier Field

- Code Identifier field contains an information which divides format and kinds of geographic address. That is, it divides whether geographic address is repres ent by ASCII format, Binary format, or code format defined by user. Also, c ode identifier divides kinds of location information represented in location inf ormation field.
- The code represented by absolute location information becomes absolute locati on code while the code represented by Geographic address, alias, area/country code, so on, becomes relative location code.
- Composition of range and distance information can be different according to c ode identifier information. Therefore, first of all you should analyze code iden tifier field of Geographic Address.

2) Range Information Field

- Range information represents an area centering the point represented in locatio n information field.
- Range Information can be variously utilized as sensing range of node, area co vering of node or error range, so on.
- It is composed of range, unit, and scale, so on. Unit indicates length such as Km, m, etc. only when range information is described. Range information fi eld may not be used to according to option.

3) Distance Information Field

- Distance information field is used to represent relative location from the point include location information field. That is, final location is away as the dista nce information from the reference point included location information field.
- Distance Information may be not used according to option. Generally distance information is not generally used since it is unnecessary information in absol ute position code.

4) Location Information Field

- Position information field includes absolute location or reference point of relat ive location.
- Absolute location information is described by latitude, longitude, and altitude while reference point of relative location is described by using various format s such as the Geographic address, alias, or area/country code, so on.
- To distinguish representation method of location information in the field, code

identifier field is used.

Detail structure of Geographic Address is as following.

<table>
<tr><th colspan="2">Code Identifier</th><th colspan="2">Range Info</th><th colspan="2">Distance Info</th><th>Location Info</th></tr>
<tr><td rowspan="6">Code Identifier</td><td rowspan="6">Field construction identifier</td><td rowspan="6">Range Option</td><td rowspan="6">Range/ Unit/ Scale</td><td rowspan="6">Distance Option</td><td rowspan="6">Distance/ Unit/ Scale</td><td>Absolute Location information</td></tr>
<tr><td>Absolute address code</td></tr>
<tr><td>Relative address code</td></tr>
<tr><td>Alias</td></tr>
<tr><td>Area code</td></tr>
<tr><td>Area code/ country code</td></tr>
</table>

Code identifier, range information, distance information fields are used generally in all Geographic Address. Location information field is described by various formats according to code identifier.

5. Examples

5.1 Expression of absolute address

When a node A in specific area such as Empires state building is represented as absolute address.

<table>
<tr><th colspan="2">Code Identifier</th><th colspan="2">Range Info</th><th colspan="2">Distance Info</th><th colspan="3" rowspan="2">Position Info</th></tr>
<tr><th>code</th><th>Field construction</th><th>option</th><th>Range (Unit)</th><th>option</th><th>Distance (Unit)</th></tr>
<tr><td>‘A’</td><td>‘X’</td><td></td><td></td><td></td><td></td><td>latitude</td><td>Longitude</td><td>altitude</td></tr>
</table>

- Code value ‘A’ : ASCII format – absolute Location Information
- Field construction value ‘X’: not used of Range Info and Distance Info fields

Detail structure of Absolute Location Information field is as following.

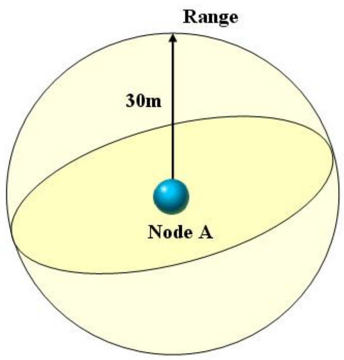
<table>
<tr><th colspan="3">Position Info</th></tr>
<tr><th>latitude</th><th>longitude</th><th>altitude</th></tr>
</table>

north / south	degrees	min	sec	east/ west	degrees	mi n	sec	height	distance	Unit

5.2 Expression of relative address

When area range centering specific point should be represented, range information field is used. The area range Information can be variously utilized as sensing range of node, area covering sensor node or error range of location, so on.

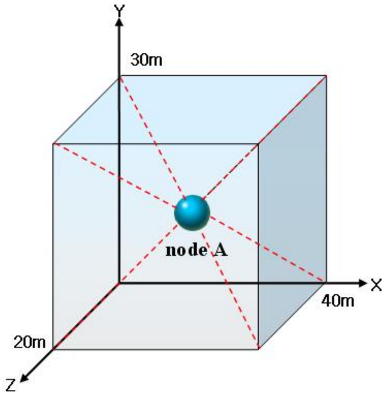
A. When range information is represented as a radius



Code Identifier		**Range Info**				**Distance Info**		**Position Info**		
code	**Field cons.**	**option**	**Range**	**Unit**	**Scale**	**option**	**Distance (Unit)**			
'A'	'C'	1	30	2				Lat i	Long	alti

- Code value 'A' : ASCII format – absolute position information
- Field construction value 'C' : not used of distance Info, expression of range info as a radius
- Range Info
  - Option '1' : not used scale, expression of range and unit as a radius
  - Unit '2': meter

B. When range information is represented as coordinates system

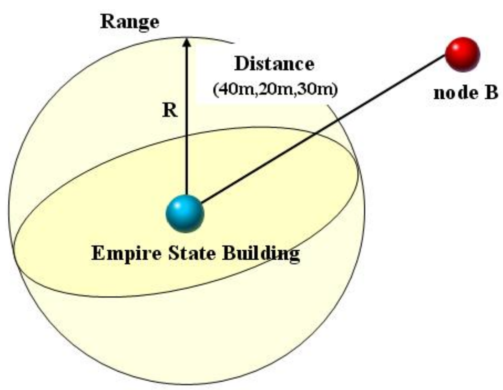


Code Identifier		Range Info				Distance Info		Position Info		
code	Field cons.	option	Range	U	Scale	option	Distance (Unit)			
‘A’	‘c’	2	RxRyRz 40 30 20	2				Lati	Long	alti

- Code value ‘A’ : ASCII format – absolute position information
- Field construction value ‘c’: not used of distance Info, expression of range info as X, Y, Z coordinates system.
- Range Info
  - Option ‘2: not used scale, expression of range as coordinates system, and used of common unit at all axis
  - Unit ‘2’: meter

5.3 Expression of relative address

When alias of the node A in empires state building is “empires state building”, a node B which is away as certain distance(40m x-axis,20m y-axis, 30m z-axis) from empires state building can be expressed by using distance information field.



Code Identifier	Range Info	Distance Info	Position Info

code	Field construction	option	Range (Unit)	option	Distance	Unit	Scale	
'D'	'D'			1	X Y Z 40 20 30	2		Empire state building

- Code value 'D' : ASCII format – alias in position info field
- Field construction value 'D': not used of Range Info, expression of Distance Info field according to distance option
- Distance Info
  - Option '1' : used of distance, used of common unit at all axis, and not used scale
  - Unit '2' : meter

6. Geographic Routing

To get us one step closer to the goal of ubiquitous computing, service coverage should be extended by deploying scalable wireless infrastructure to provide seamless internet service for users. Currently, research area of providing Internet connectivity to mobile nodes in wireless multi-hop networks which can reduce the cost of Infrastructure and provide the ubiquitous Internet access has been significant upsurge. When wireless multi-hop network are connected with Internet, service area of Internet could be extended into wireless multi-hop network and mobile nodes communicating with access router through shorter distance of multi-hop connection rather than single hop could reduce power consumption for transmission. To provide high performance and effective cost in network deployment for ubiquitous environment, wireless multi-hop networks with Internet connectivity are suitable because wireless multi-hop networks are highly scalable, flexible and easy to deploy wireless networks.

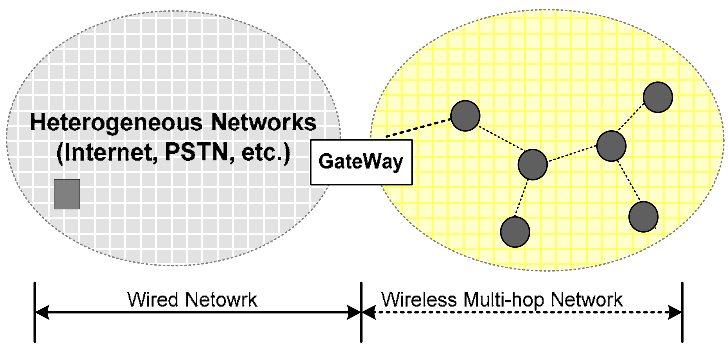


Figure2. Wireless Multi-hop Network with Internet connectivity

Geographic Routing which is one of multi-hop routing methods generally uses greedy forwarding method to forward packets to nodes that are always progressively closer to the destination by using location information. Geographic routing method minimizes routing overhead because it does not need procedure route discovery such as reactive routing protocols (ex. AODV) and maintain information for routing states. Therefore, geographic routing is scalable to mobility and load.

This paper describes a new geographic routing algorithm which provides nodes with efficient communication by using a new geographic address scheme in wireless multi-hop network with Internet connectivity.

6.1 A New Geographic Routing Algorithm

A New Geographic Routing algorithm consists of three routing methods which are Location-Based Routing (LBR), restricted Topology-Based Routing (TBR) in wireless multi-hop network and Gateway Traversal Routing (GTR) for Internet connectivity. This routing algorithm for scalable wireless multi-hop networks with Internet connectivity can help to provide the ubiquitous computing.

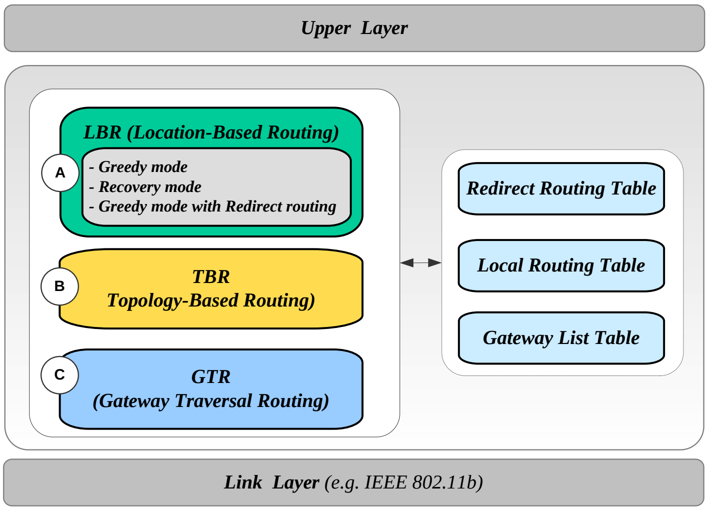


Figure3. Components of a new geographic routing

1) Location-Based Routing method (LBR)

To forward packet to destination, each node basically uses greedy forwarding that source and each intermediate node route packets to a neighbor node(next hop) closest to a destination. However, greedy forwarding does not operate when no neighbors is closer than current node to a destination. The node is called dead-end and the problem of being stuck packets at dead-end nodes is known as void, hole or local-minimum.

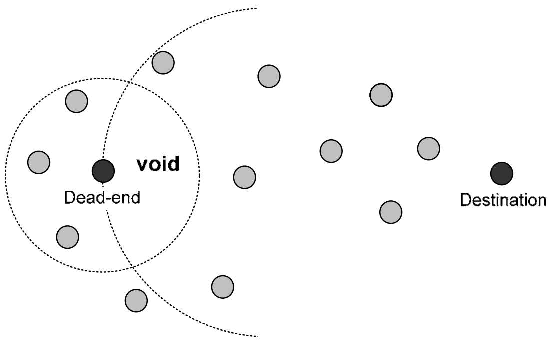
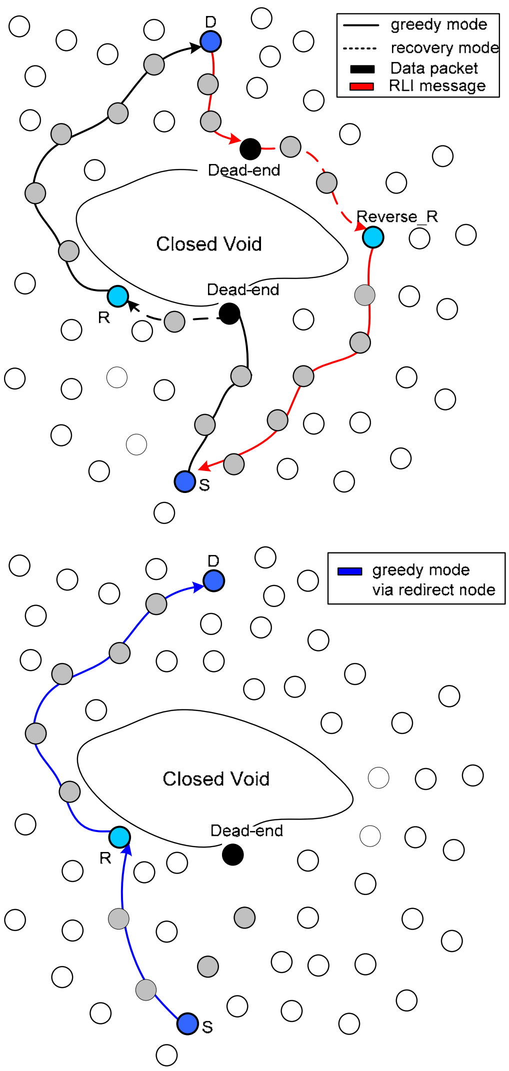


Figure4. An example of dead-end

To solve void problem and improve routing efficiency, LBR consists of greedy mode, recovery mode and greedy mode with redirect routing.

When a packet is stuck at dead-end, the dead-end node starts route recovery mode like perimeter mode of Greedy Perimeter Stateless Routing(GPSR); perimeter mode forwards packets along successively closer faces by right-hand rule. Packets return to greedy mode upon reaching a node closer to destination than perimeter mode entry point node(dead-end node).

In LBR, when an intermediate node receiving the packet is closer than the dead-end node to destination, the intermediate node called *redirect node* records own information in redirect list field of routing header and restarts greedy forwarding. If a packet arriving destination includes information of redirect node list, the destination transmits a control message called RLI(Redirect List Information) including the redirect list information to the source. If the control message to source is stuck at a dead-end, an immediate node called *reverse redirect node* records itself information in reverse redirect list field of RLI. To forward packets through shorter path, the source selects one of two paths based on forward path hop count from source to destination and reverse path hop count from destination to source. Therefore, the source transmitting later packet toward same destination utilizes redirect routing header which allows a packet to forward toward destination via redirect node(s) and to avoid forwarding to dead-end node.



(a) LBR(greedy mode and recovery mode) (b) LBR using redirect routing header

Figure5. An example of LBR

LBR method part helps that packets efficiently route around voids by avoiding local-minimum.

(2) Restricted Topology-Based Routing (TBR)

In practical wireless multi-hop networks, source node may not know accurate location information of destination because destination's location frequently changes. Therefore, LBR alone is not sufficient to forward packet because LBR may cause routing loop due to inaccuracy of destination's location information. Each node maintains local topology information within 2-hop by periodically broadcasting Neighbor Information (NI) message within 1 hop. NI message includes sender's information and own 1-hop neighbors' ID. When a source node or an intermediate node transmitting a packet is within two hops away from destination node, the node forwards the packet using local topology information not location-based routing.

TBR method part reduces probability of routing loop due to inaccuracy of destination's location in scalable wireless multi-hop networks.

(3) Gateway Traversal Routing (GTR)

To offer Internet access, nodes within 1 hop away from gateway maintain gateway(s) information by receiving router advertisement message from gateway(s). Nodes within 2 hops away from gateway(s) acquire the gateway(s) information by receiving NI message including gateway list field option from the nodes within 1 hop away from gateway(s). Nodes within multi-hop networks progressively become aware of gateway(s) information by periodically NI message. Each node can configure global IP address by using gateway's prefix information.

Each node which manages gateway(s) information in own gateway list table determines whether destination is within multi-hop network or not by comparing destination's prefix with gateway's prefix. If the destination is Internet node, source sends a packet with GTR(Gateway Traversal Routing) header to traverse own default gateway and each intermediate node forwards the packet toward the gateway.