International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

Y.2615

(07/2012)

SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS AND NEXT-GENERATION NETWORKS

Next Generation Networks – Packet-based Networks

Routing mechanisms in public packet telecommunication data networks

Recommendation ITU-T Y.2615

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ITU-T Y-SERIES RECOMMENDATIONS

GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS AND NEXT-GENERATION NETWORKS

GLOBAL INFORMATION INFRASTRUCTURE	
General	Y.100–Y.199
Services, applications and middleware	Y.200–Y.299
Network aspects	Y.300–Y.399
Interfaces and protocols	Y.400–Y.499
Numbering, addressing and naming	Y.500–Y.599
Operation, administration and maintenance	Y.600–Y.699
Security	Y.700–Y.799
Performances	Y.800–Y.899
INTERNET PROTOCOL ASPECTS	
General	Y.1000–Y.1099
Services and applications	Y.1100–Y.1199
Architecture, access, network capabilities and resource management	Y.1200–Y.1299
Transport	Y.1300–Y.1399
Interworking	Y.1400–Y.1499
Quality of service and network performance	Y.1500–Y.1599
Signalling	Y.1600–Y.1699
Operation, administration and maintenance	Y.1700–Y.1799
Charging	Y.1800–Y.1899
IPTV over NGN	Y.1900–Y.1999
NEXT GENERATION NETWORKS	
Frameworks and functional architecture models	Y.2000–Y.2099
Quality of Service and performance	Y.2100–Y.2199
Service aspects: Service capabilities and service architecture	Y.2200–Y.2249
Service aspects: Interoperability of services and networks in NGN	Y.2250–Y.2299
Numbering, naming and addressing	Y.2300–Y.2399
Network management	Y.2400–Y.2499
Network control architectures and protocols	Y.2500–Y.2599
Packet-based Networks	**Y.2600–Y.2699**
Security	Y.2700–Y.2799
Generalized mobility	Y.2800–Y.2899
Carrier grade open environment	Y.2900–Y.2999
FUTURE NETWORKS	Y.3000–Y.3499
CLOUD COMPUTING	Y.3500–Y.3999

For further details, please refer to the list of ITU-T Recommendations.

Recommendation ITU-T Y.2615

Routing mechanisms in public packet telecommunication data networks

Summary

As one hierarchical packet data network which can meet requirements of future packet-based networks (FPBNs), the public packet telecom data network (PTDN) provides a solution of efficient and reliable routing mechanisms. Recommendation ITU-T Y.2615 illustrates the PTDN routing architecture, routing models and the corresponding routing mechanisms, such as topology construction, intra-domain routing, inter-domain routing and routing procedures.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T Y.2615	2012-07-29	13

Keywords

Alternative routing, dual path routing, PTDN, routing architecture, shortest path routing.

FOREWORD

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Table of Contents

Recommendation ITU-T Y.2615

Routing mechanisms in public packet telecommunication data networks

1 Scope

This Recommendation identifies the routing mechanisms of the public packet telecom data network (PTDN), including routing architecture, routing models and corresponding routing mechanisms, such as topology construction, intra-domain routing, inter-domain routing and routing procedure.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T Y.2601] Recommendation ITU-T Y.2601 (2006), *Fundamental characteristics and requirements of future packet based networks*.

[ITU-T Y.2611] Recommendation ITU-T Y.2611 (2006), *High-level architecture of future packet-based networks*.

[ITU-T Y.2612] Recommendation ITU-T Y.2612 (2009), *Generic requirements and framework of addressing, routing and forwarding in future, packet-based networks*.

[ITU-T Y.2613] Recommendation ITU-T Y.2613 (2010), *General technical architecture for public packet telecommunication data network*.

[ITU-T Y.2614] Recommendation ITU-T Y.2614 (2011), *Network reliability in public telecommunication data networks*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 address [ITU-T Y.2601]: An address is the identifier for a specific termination point and is used for routing to this termination point.

NOTE – Identifiers can be used for registration or authorization. They can be either public to all networks, shared between a limited number of networks or private to a specific network (private identifiers are normally not disclosed to third parties).

3.1.2 alternative routing model [ITU-T Y.2614]: A routing model providing multiple paths between a source public packet telecommunication data network (PTDN) node and a destination PTDN node.

NOTE – These paths are not required to be deterministic and unique. In this model, the sending path and the receiving path are not necessarily composed of the same nodes and links.

3.1.3 dual path routing model [ITU-T Y.2614]: A routing model providing two totally disjoint paths between a source public packet telecommunication data network (PTDN) node and a destination PTDN node.

NOTE – The two paths may not be the shortest paths.

3.1.4 public packet telecommunication data network (PTDN) [ITU-T Y.2613]: A packet data network designed for the NGN transport stratum, which should be secure, trustworthy, controllable, and manageable, can meet all the requirements described in [ITU-T Y.2601]. PTDN is a hierarchical network, which can be subdivided into several network layers.

3.1.5 shortest path routing model [ITU-T Y.2614]: A routing model providing a deterministic and unique path, which is the shortest path from a source PTDN node to a destination PTDN node.

NOTE – In this model, the path from the source node to the destination node results in the same as the path from the destination node to the source node.

3.1.6 trail protection [b-ITU-T G.780]: Normal traffic is carried over/selected from a protection trail instead of a working trail if the working trail fails, or if its performance falls below a required level.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 dominant node: A PTDN node in a domain, which is responsible for calculating routing and generating a routing table for every PTDN node in the domain.

3.2.2 ear decomposition: An ear decomposition $D = \{P_0; P_1;\ldots; P_{r-1}\}$ of an undirected graph $G = (V, E)$ is a partition of E into an ordered collection of edge-disjoint simple paths $P_0; P_1;\ldots; P_{r-1}$, called ears, such that:

- P_0 is a simple cycle.
- P_i (i>0) is a simple path with the end-points belonging to lower-numbered ears, and with no internal vertices belonging to lower-numbered ears.
- P_i (i>0) may also be a simple cycle. If it is a cycle consisting of only one edge, it is called a trivial ear.

3.2.3 potential energy: A numerical value derived from the PTDN node address, which should be unique to the node and can be used for selecting one path from multiple redundant paths. In the shortest path routing model, the potential energy values of the nodes on the paths are used to choose one path when several paths have the same cost as the shortest path.

3.2.4 ST number: After ear decomposition, the nodes in a domain will be renumbered according to the results of decomposition with spanning tree (ST) numbers, which are used to form two node-disjoint paths from source node to destination node.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

NNI	Network to Network Interface
PTDN	Public packet Telecom Data Network
QoS	Quality of Service
ST	Spanning Tree
TTL	Time To Live

UNI User to Network Interface

VPN Virtual Private Network

5 Routing architecture

The address space of the PTDN is hierarchical, and the addresses of the PTDN are allocated subject to geographical distribution. The prefix of the PTDN address contains the hierarchical information. In the PTDN, a domain is composed of a group of nodes under a single administration and with common routing policies. The nodes in a domain usually have an identical address prefix, use common metrics to route packets and share the same routing table information. The relationship between nodes which are in the same domain is called intra-domain and the relationship between nodes which are in different domains is called inter-domain.

The example given in Figure 1 illustrates the concept of domains. There are four domains in this PTDN network: domain 1, domain 2, domain 3 and domain 4. The nodes in domain 1, which are located in the core layer, has the address prefix "1000 0000 0000". There are two domains in the access layer: domain 3 and domain 4, and the prefixes are "1000 1000 1000" and "1000 1000 2000", respectively.

The routing mechanism of the PTDN is divided into two levels: the intra-domain routing mechanism and inter-domain routing mechanism.

The routing within a domain, such as from node d to node h, is called intra-domain routing. The routing across domains, such as from node f to node m and from node g to node j, is called inter-domain routing.

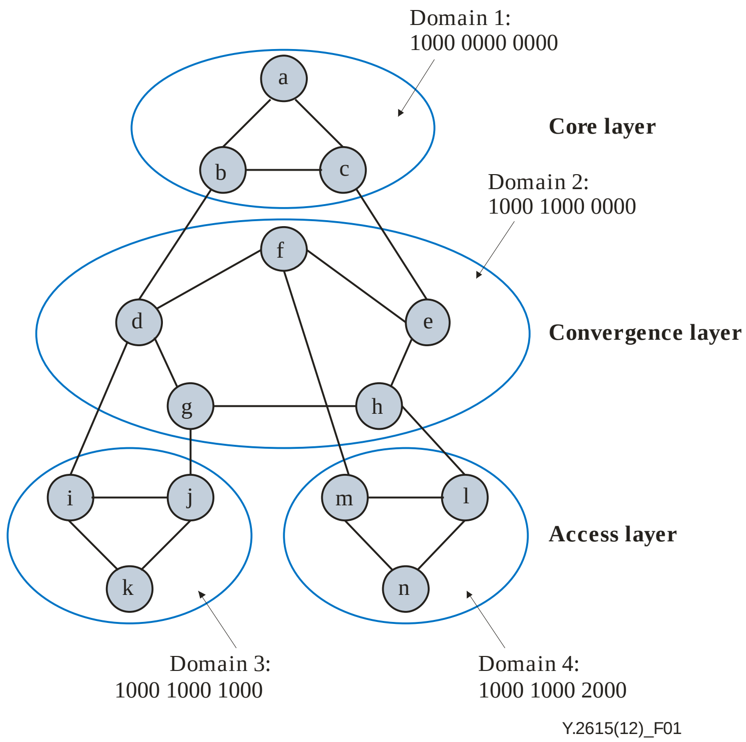

Figure 1 – Illustration of domains in the PTDN

5.1 Intra-domain routing mechanism

The intra-domain routing mechanism can be divided into two parts: one part establishes the intra-domain routing table, the other produces two kinds of forwarding tables – the inter-domain forwarding table and the intra-domain forwarding table.

(1) When a boundary node in a domain transfers routing information (e.g., domain prefix or address) of other domains within the domain, the inter-domain forwarding table will be established based on the intra-domain routing table. Then the routing information of these other domains will be transferred based on the inter-domain forwarding table to other boundary nodes in the current domain, which connects to other domains.

(2) When packets arrive at the destination domain or the source PTDN node and the destination PTDN node is located in the same domain, the node will establish the intra-domain forwarding table based on the intra-domain routing table. Packets will be forwarded to the destination PTDN node based on the intra-domain forwarding table.

In the PTDN intra-domain routing mechanism, the potential energy of PTDN nodes will be used to construct the routing table.

5.2 Inter-domain routing mechanism

The inter-domain routing mechanism can be divided into two parts: one is the within-domain part; the other is the cross-domain part.

The within-domain part establishes intra-domain forwarding tables which are usually used for transferring within a domain address prefixes that are from other domains. The cross-domain part transfers routing information (e.g., domain prefixes or addresses) of other domains among boundary nodes by the inter-domain forwarding table.

There can be multiple inter-domain connections, and only the best inter-domain connection is active when the shortest path routing model or dual path routing model is applied. The best inter-domain connection is selected based on three parameters: priorities, transmission rate and node address. The priority of a connection can be configured manually. All of these multiple inter-domain connections will be used under the alternative routing model and the multiple paths are differentiated based on cost.

6 Routing models

There are three routing models in the PTDN routing mechanism: the shortest path routing model, dual path routing model and alternative routing model. These three models provide different functions and are applied in different scenarios.

There are two bits in the header of a PTDN packet to identify four routing policies under three PTDN routing models:

00: Shortest path routing model;

01: Dual path routing model (working path);

10: Dual path routing model (protection path);

11: Alternative routing model.

6.1 Shortest path routing model

The shortest path routing model provides a deterministic and unique path, which has the minimum cost, between every pair of distinct PTDN nodes in a domain. In this model, the path from the source node to the destination node results in the same as the path from the destination node to the source node. When the shortest path routing model is applied, QoS can be guaranteed.

If there are multiple inter-domain connections, only one connection is active to carry all traffic between the two domains, and other inter-domain connections are deactivated when the shortest path routing model is applied.

There may be several paths in the routing table corresponding to different inter-domain connections. Only the path corresponding to the active inter-domain connection will be installed to the forwarding table to help forwarding the packets.

6.2 Dual path routing model

The dual path routing model provides two deterministic and totally disjoint paths between every pair of distinct PTDN nodes in a domain. In this model, both the sending path and receiving path are composed of the same nodes and links. When the dual path routing model is applied, QoS can be guaranteed.

The dual path routing model can provide the function of trail protection, while the model does not guarantee that these two disjoint paths are the shortest paths.

If there are multiple inter-domain connections, only one connection is active to carry all traffic between the two domains, and other inter-domain connections are deactivated when the dual path routing model is applied.

Only the active inter-domain connection will be installed to the forwarding table.

The dual path routing model can be applied only if the network topology fulfils two conditions:

(1) the network graph is two-edge connected;

(2) the network graph is bi-direction connected.

NOTE – An edge $e \in E$ in a connected graph G = (V, E) is a cut edge if e does not lie on a cycle in G. A connected undirected graph G = (V, E) is two-edge connected if it contains no cut edge.

6.3 Alternative routing model

The alternative routing model provides many paths between every pair of distinct PTDN nodes in a domain. These paths do not need to be deterministic and unique. The sending path and receiving path in this model do not need to be composed of the same nodes and links. The working path of the alternative routing model does not need to be the shortest path. When the alternative routing model is applied, QoS may not be guaranteed.

The alternative routing model can provide the function of trail protection for the shortest path routing model. When the shortest path routing model fails, the alternative routing model can be applied to keep communication open between nodes.

If there are multiple inter-domain connections, all these connections will be sequenced by the cost of each connection and the corresponding forwarding tables will be applied orderly.

7 Shortest path routing model

7.1 Construction of topology

In the shortest path routing model, every PTDN node maintains the same topology which contains all nodes and link information between nodes in the domain. The set-up procedure of topology is defined as follows.

(1) Configure an address for every active node and a cost for every active link (the cost is calculated based on the priority, bandwidth and other connection information).

(2) Exchange configuration information between neighbour nodes.

(3) Exchange the address and link state information of every PTDN node within a domain.

7.2 The intra-domain routing

A dominant node is a PTDN node in a domain, which is responsible for calculating paths between nodes and generating routing tables for PTDN nodes in the domain.

The PTDN node that has the minimum node address in a domain is assigned as the dominant node. The PTDN node that has the secondary minimum node address in the domain is assigned as the backup of the dominant node.

In the shortest path routing model, the dominant node calculates the path with the minimum cost for every pair of distinct PTDN nodes based on the cost. If there are several next hops with the same minimum cost for a pair of distinct PTDN nodes, the next hop node with the potential energy closest to the current PTDN node will be selected as the next hop node. The routing table will be established after this process.

Based on the routing table, a dominant node calculates a forwarding table for every node in the domain and then sends the forwarding table to all the nodes within the domain.

7.3 The inter-domain routing

The inter-domain routing in the shortest path routing model is composed of two parts, which are the cross-domain routing protocol and within-domain routing protocol.

The cross-domain routing protocol runs among domains, and is used to exchange prefix information between the PTDN border nodes among different domains. By using the cross-domain routing protocol, the inter-domain routing policy can be achieved. In shortest path routing model, if there are multiple connections between domains, connections will be sorted according to their cost. The connection with the minimum cost will be active to carry the service traffic and the others will be deactivated. The priorities of inter-domain connections can be set manually.

The within-domain routing protocol runs inside a domain, and is used to transfer routing information within the domain.

8 Dual path routing model

8.1 Construction of topology

In the dual path routing model, every PTDN node maintains the same topology which contains all nodes and link information between nodes in the domain. The set-up procedure of topology is defined as follows.

(1) Configure every active node an address and every active link a cost, which is calculated based on the priority, bandwidth and other connection information.

(2) Generate the spanning tree that covers all nodes within the domain.

(3) Exchange the address and link state information of every PTDN node in the domain.

8.2 The intra-domain routing

In the dual path routing model, the dominant node calculates two totally disjoint paths for every pair of distinct PTDN nodes after it has been aware of the topology. In this process, the dual path forwarding table can be set up through management order (centralized) or control order (decentralized).

The dominant node will perform the following steps to generate two disjoint paths.

(1) Perform an ear decomposition for the nodes and links in the PTDN domain.

(2) Generate a spanning tree (ST) number for every PTDN node in the current domain.

(3) Construct two disjoint paths based on the result of ear decomposition and ST number, which are the working path and the protection path.

NOTE – The detail of this process is described in Annex A.

8.3 The inter-domain routing

The inter-domain routing in the dual path routing model is composed of two parts: the cross-domain routing protocol and within-domain routing protocol.

The cross-domain routing protocol runs among domains and is used to exchange routing information between the PTDN border nodes among different domains. By using the cross-domain routing protocol, the inter-domain routing policy can be achieved.

In the dual path routing model, if there are multiple connections between domains, connections will be sorted according to their cost. The two connections with minimum cost will be chosen; one of them will be active to carry the traffic, and the other connection will be a backup and not active. The priorities of inter-domain connections can be set manually.

The within-domain routing protocol runs inside a domain and is used to transfer prefix information in the domain.

9 Alternative routing model

9.1 Construction of topology

In the alternative routing model, every PTDN node maintains the same topology which contains all nodes and link information between nodes in the domain. The set-up procedure of topology is defined as follows.

(1) Configure every active node an address and every active link a cost, which is calculated based on the priority, bandwidth and other connection information.

(2) Exchange configuration information between neighbour nodes.

(3) Broadcast the address and link state information of every PTDN node in domain.

9.2 The intra-domain routing

A dominant node is a PTDN node in a domain that is responsible for calculating routing and generating a routing table for every PTDN node in the domain. The routing table generated by the dominant node contains many different intra-domain paths for every pair of source PTDN nodes and destination PTDN nodes in the domain in the alternative routing model. The dominant node will therefore send the generated routing table to every PTDN node in the domain.

The PTDN node that has the minimum node address in a domain is assigned as dominant node in the domain. The PTDN node that has the secondary minimum node address in the domain is assigned as the backup of the dominant node.

Many paths from a source PTDN node to a destination PTDN node are sorted in the routing table by cost order. Only the path with the minimum cost will be installed into the forwarding table.

The cost of paths in the alternative routing model may be changed due to the change of link state or node failure. The change of path cost will be compared with a predefined threshold value in order to assess whether the routing table should be re-sorted. If the routing table is adjusted due to the change of cost of paths, the forwarding table will be modified correspondingly to ensure that only the next hop with minimum cost is installed into the forwarding table.

9.3 The inter-domain routing

The inter-domain routing in the alternative routing model is composed of two parts: the cross-domain routing protocol and within-domain routing protocol.

The cross-domain routing protocol runs among domains and is used to exchange prefix information between the PTDN border nodes among different domains. By using the cross-domain routing protocol, the inter-domain routing policy can be achieved. In the alternative routing model, if there are multiple connections between domains, connections will be sorted according to their cost, which is calculated based on the priority, bandwidth and other connection information. The priorities of inter-domain connections can be set manually by the network operator. All inter-domain connections can be active in the alternative routing model.

The within-domain routing protocol runs inside a domain, and is used to transfer prefix information in the domain. The forwarding table generated by intra-domain routing will be used by the within-domain routing protocol.

10 Routing procedure

The routing procedure of the PTDN is defined as follows.

(1) When a PTDN packet arrives, the PTDN node checks the protection field (2 bits, defined in [ITU-T Y.2613]) in the packet's header field: if the protection field equals 00, the shortest path routing model will be applied; if the protection field equals 11, the alternative routing model will be applied; if the protection field equals 01, the dual path routing model will be applied and the working path will be used for packet forwarding; if the protection field equals 10, the dual path routing model will be applied and the protection path will be used for packet forwarding.

(2) If the shortest path routing model is applied, the node will search for a shortest path in the corresponding forwarding table; if it fails, the routing process goes to step (4). If the dual path routing model is applied, the node will first search for the working path in the corresponding forwarding table when the protection field equals 01; if this attempt fails, the node will go on to search the protection path; if it also fails, the routing process goes to step (4). When the protection field equals 10, the node will first search for the protection path in the corresponding forwarding table; if this attempt fails, the node will go on to search the working path; if it also fails, the routing process goes to step (4). If the alternative routing model is applied, multiple paths may be found in the corresponding forwarding table and theoretically the node working in this model can choose more than one next-hop to route packets, and packets can be transferred at the path with minimum cost. If this attempt fails, the node will choose the secondary cost path, and so on. When searching the forwarding table, the longest prefix match principle will be used for next-hop determination.

(3) After the node finds next-hop according to the corresponding forwarding table, packets are transferred and the TTL (6 bits, defined in [ITU-T Y.2613]) field is reduced by one on each hop.

(4) If there are no items in the corresponding forwarding table matching the destination of the arriving packet, the default forwarding path will be used.

11 Security considerations

There are two aspects of security consideration for PTDN routing mechanisms:

- security guarantee of control plane;
- security guarantee of network connectivity.

11.1 Security guarantee of control plane

Certain VPNs are used for the PTDN control plane, which carries routing messages. These VPNs have the following security features.

- Isolation: VPNs for the control plane are isolated from each other and they are isolated from other VPNs for different purposes rather than the control plane.
- Resource guarantee: The resources of VPNs for the control plane are guaranteed absolutely and with the highest priority.
- Separation between the NNI and UNI: Routing data can be only exposed within the specific VPN. Unauthorized users cannot intrude into these VPNs.

11.2 Security guarantee of network connectivity

In the PTDN there are three routing mechanisms. Two of them can provide redundant path connections between ends to guarantee network connectivity.

In the dual path routing mechanism, the routing mechanism provides two totally independent protection routes for packet forwarding in connectionless mode. The two routes back up each other.

In the alternative routing mechanism, the routing mechanism provides several paths between every pair of distinct PTDN nodes in a domain. These paths can back up each other.

In some scenarios the network administrator of the PTDN may configure static routing via PTDN management functions. The process shall be performed in accordance with the security rule of the PTDN M interface, which is illustrated in another ITU-T Recommendation.

No additional risks involving these routing mechanisms have been identified.

Annex A

Path calculation in the dual path routing model

(This annex forms an integral part of this Recommendation.)

A.1 Construction of protection paths

The dual path routing model in the PTDN routing mechanism provides two totally independent protection routes for packets forwarding in connectionless mode; one of them is called the red path, and the other is called the blue path.

Computation of the protection routes is not computationally extensive. Each PTDN node will perform the following steps to provide protection for the intra-domain path.

1) Perform an ear decomposition for the nodes and links in the PTDN domain.

2) Generate an ST number for every PTDN node in the current domain.

3) Construct the protection routes based on the ear decomposition and ST number, which are the red protection path and the blue protection path.

A.2 Ear decomposition

An ear decomposition $D = \{P_0; P_1;\ldots; P_{r-1}\}$ of an undirected graph $G = (V, E)$ is a partition of E into an ordered collection of edge-disjoint simple paths $P_0; P_1;\ldots; P_{r-1}$, called ears, such that:

- P_0 is a simple cycle;
- P_i (i>0) is a simple path with the end-points belonging to lower-numbered ears, and with no internal vertices belonging to lower-numbered ears;
- P_i (i>0) may also be a simple cycle. If it is a cycle consisting of only one edge, it is called a trivial ear.

An ear decomposition is called open if and only if there is no cycle for P_i (i>0).

In Figure A.1, the network topology shown at the left is decomposed into four ears, as shown at the right. Among them, P_0 is a simple cycle composed of nodes 0, 1, 3 and 6; P_1 is composed of nodes 2, 4 and 7, with end-points 3 and 0 belonging to ear P_0, which is the lower-numbered ear compared to P_1; P_2 is composed of nodes 5 and 8, with end-points 2 and 6 belonging to ears P_1 and P_0, respectively, which are the lower-numbered ears compared to P_2; P_3 is composed of node 9, with end-points 7 and 8 belonging to ears P_1 and P_2, respectively, which are the lower-numbered ears compared to P_3.

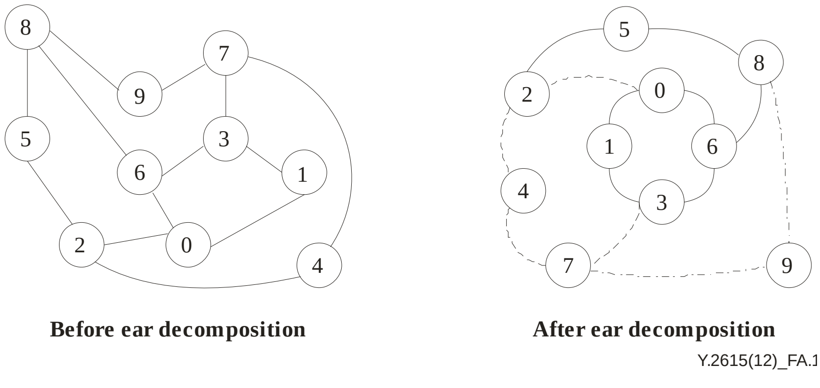

Figure A.1 – Ear decomposition

Ear decomposition exists if and only if the graph is 2-edge connected. In the PTDN network, a 2-edge connected graph can provide protection for link failure and nodal failures.

A process of ear decomposition can be partitioned into the following steps:

(1) constructing a minimum spanning tree;

(2) rooting the minimum spanning tree;

(3) pre-ordering the minimum spanning tree;

(4) labelling each non-tree edge by the number of the lowest common ancestor of its end-points in the minimum spanning tree and assigning ear numbers to the non-tree edge by sorting the non-tree edges according to their lowest common ancestor in ascending order;

(5) assigning ear numbers to tree edges.

A.3 Generation of ST number

The construction of those directed sub-graphs involves the orientation of the ears and obtaining the ST numbers for each of the vertices. The ST number will be used to construct the red routes and blue routes.

The ST number will be obtained by the following procedure.

(1) Choose the vertex in P_0 with the smallest PTDN address. The vertex is noted as v_s. There exist two other vertices, which are in P_0 and are adjacent to vertex v_s (because of the existence of the open ear decomposition and the assumption of a simple graph). The one with the smaller of the PTDN addresses between the two will be selected and be denoted as v_t.

(2) The P_0 will be directed in such way that the direction on the edge $\{v_s, v_t\}$ will be from vertex v_t to vertex v_s. The direction on the other edges of P_0 will ensure that P_0 forms a cycle on the directed sub-graph (i.e., the direction of the path will start at vertex v_s, traverse along the inner vertices of P_0 and reach v_t).

(3) An ordered list (O_{st}) of all the vertices in P_0 will be constructed, starting with v_s and ending at v_t along the directed edges to include all the inner vertices of the P_0 (i.e., not following the direct connected edge $\{v_s, v_t\}$). After all the ears are included, a given vertex will appear once in the ordered list O_{st}. The index used to identify the vertex in the ordered list O_{st} will then be the ST number for the vertex.

(4) For ear P_i with vertices u and v in $\{P_0, P_1,\ldots, P_{i-1}\}$ (the start and end of the ear), if the index for vertex u is smaller than that of vertex v in the ordered list O_{st} (i.e., u appears before the vertex v in the list), the orientation of the ear P_i will be from u to v. The inner vertices of the ear P_i will be added to the ordered list O_{st}, at the location after vertex u and along the direction from vertex u to vertex v.

(5) Repeat step 4 until all the ears are included.

A.4 Construction of protection routes

The protective routes will be constructed based on ear decomposition and ST number. The computing rules can be described as follows.

(1) If the red protection path is constructed in ascending order of ST numbers, the blue protection path will be constructed in descending order of ST numbers, and vice versa.

(2) If packets are forwarded in ascending order of ST numbers from the source PTDN node to the destination PTDN node, packets will be forwarded in descending order of ST numbers when forwarded back to the source PTDN node, and vice versa.

(3) If there are multiple neighbour PTDN nodes in which ST numbers are in the ascending (descending) direction, the ST number which is closest to the destination PTDN node will be selected as next hop.

(4) The ST number of next hop should not exceed the ST number of the destination PTDN node along ascending (or descending) order.

A.5 Construction of link state database

The link state database, which is used to calculate the red path and blue path, is generated by the dominant node in the domain based on the result of ear decomposition and is broadcasted throughout the domain. Every node in the domain has the same link state database. The link state database is composed of link states of every node in the domain, which include the following items.

- Type: Indicates the path that will be calculated using the link state; 0: blue path, 1: red path.
- PTDN node: The network address of the current PTDN node.
- Number of links: The number of links that connect the current node.
- Neighbour node: The network address of neighbouring PTDN nodes.
- Interface: The interface connects to the corresponding neighbour node.
- Link weight: If this link is active in the red path (or blue path), its link weight will be set to 1, otherwise its link weight will be set to 888 (or other large value).

Table A.1 is an example of the link state.

Table A.1 – Link state of a PTDN node

Type (0: blue path; 1: red path)
PTDN node (network address of current PTDN node)
Number of links
Description of link 1 (neighbour node, interface, link weight)
Description of link 2 (neighbour node, interface, link weight)
……

The link state database is composed of the link state of all PTDN nodes in the domain. The red path link state database is used to calculate the red path and the blue path link state database is used to calculate the blue path.

Actually, only the blue (or red) link state database needs to be kept, and the other link state database, that is, the red (if the blue link state database is kept) or blue (if the red link state database is kept) link state database will be calculated by reversing the values of link weight.

An example of directed sub-graphs is shown in Figure A.2, with the ST number in the []. The left part of the figure is the directed sub-graph for the blue path, in which the ST number increases along the direction except at node 0. The right part of the figure is the directed sub-graph for the red path, in which the ST number descends along the direction except at node 0. For the blue data link state database, only the links, in which the neighbour node's ST number is greater than the current node, are active. For the red data link state database, only the links, in which the neighbour node's ST number is less than current node, are active.

The PTDN node 0 in Figure A.2 might have a blue link state that looks like Table A.2, and a red link state that looks like Table A.3, in which the link weight is reversed from the blue link state.

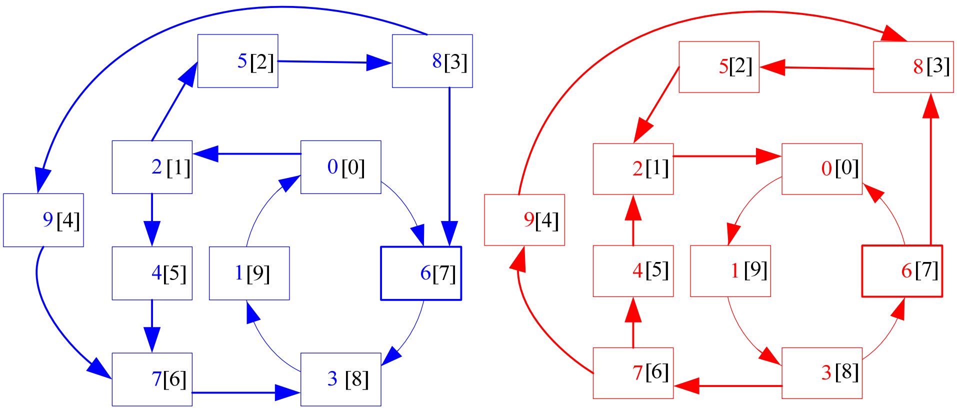

Figure A.2 – Directed sub-graphs for blue path (left) and red path (right)

Table A.2 – Blue link state of node 0

Type (0)
PTDN node (0)
Number of links (0)
Description of link 1: Neighbour node: 2 Interface: Serial 0 Link weight: 1 (active)
Description of link 2: Neighbour node: 1 Interface: Serial 1 Link weight: 888 (inactive)
Description of link 3: Neighbour node: 6 Interface: Serial 2 Link weight: 1 (active)

Table A.3 – Red link state of node 0

Type (1)
PTDN node (0)
Number of links (3)
Description of link 1: Neighbour node: 2 Interface: Serial 0 Link weight: 888 (inactive)
Description of link 2: Neighbour node: 1 Interface: Serial 1 Link weight: 1 (active)
Description of link 3: Neighbour node: 6 Interface: Serial 2 Link weight: 888 (inactive)

A.6 Forwarding table

The routing table is based on the link state database and the forwarding table is based on the routing table. The forwarding table is used for data forwarding. There are two forwarding tables in the dual path routing model; one is for the blue path and the other is for the red path. The forwarding table includes the following items.

- Destination address: Indicates the address of the destination network or destination PTDN node.
- Colour: A colour flag simply indicates which path the forwarding table is for; 0 indicates the blue path and 1 indicates the red path.
- Interface: Indicates the serial number of interface.
- Next hop: Indicates the address of next hop.

A PTDN node may have a forwarding table for the dual path routing model that looks like Table A.4.

Table A.4 – An example of a forwarding table in a dual path routing model

Destination address	Colour	Interface	Next hop
1000 0000 0000 xxxx	Red	Serial 0	1000 1000 0000 0012
1000 0000 0000 xxxx	Blue	Serial 1	1000 1000 0000 0008

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Printed in Switzerland
Geneva, 2013