Node-failure robustness of inter-layer 3 networking with ID/Locator separation architecture

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Abstract: ID/Locator separation architecture is proposed in order to reduce routing table size in the current Internet. In this architecture, an end-host can be identified by unique ID which is independent of its network protocol. Network protocol independency of ID provides possibility of communication with end hosts operating different network-layer protocol. This inter-layer 3 networking brings several benefits in addition to routing table size improvement, e.g. improvement of shortest path and robustness. In our previous paper, performance of inter-layer 3 networking from the viewpoint of shortest path improvement has been evaluated. In this paper, we focus on improvement of robustness brought by inter-layer 3 networking in the case of node failure. Node failure generally suffers serious degradation of connectivity because all links connected to a node are failed. Our simulation results show that significant improvement of robustness can be obtained only with small number of vertical links going through multiple network planes.

Keywords: ID/Locator separation, inter-layer 3 networking, robustness, node-failure

Classification: Network

References


1 Introduction

In the current Internet, address defined in network layer (IP) includes subnet prefix. This network ID part of IP address is a location-oriented address. So, with host mobility or multi-homing which is not suitably operated by location-based address causes severe increase of routing entries in Default Free Zone [1]. One promising way to resolve this technical problem caused by host mobility and multi-homing is ID/Locator separation [2, 3]. In ID/Locator separation architecture, ID is clearly separated from Locator and is independent of its location. In core network, an ID is translated to a Locator which is valid (only) for the corresponding network and packets are forwarded by Locator. When a host moves, its ID remains unchanged but a Locator is translated to a new one valid for the corresponding network. Thus, Locator can have a clear hierarchical structure in each domain, which enables effective address aggregation and significantly reduces routing table entries in core networks.

ID/Locator separation architecture brings another benefit than routing table entry reduction, inter-layer 3 networking in which a host can communicate with another host in different layer 3 networks [4, 5]. User-perceived performance improvement brought by inter-layer 3 networking is improvement of path length and robustness. In our previous work [6], the former performance has already evaluated. In this paper, we would like to evaluate another important user-perceived performance improvement, robustness. For robustness of inter-layer 3 networking, link-failure case has been evaluated in our conference paper [7]. In this paper, robustness for more serious situation, node-failure, is evaluated.

2 Inter-layer 3 networking with ID/Locator separation

In inter-layer 3 networking, nodes (routers) connecting multiple network protocol planes bridge a packet towards a different network protocol plane. We
call this node a *shared node* because it is shared by multiple protocol planes. Transition to a different network protocol plane inside a shared node can be interpreted as a packet transmission on a virtual link in a router (it is really a transition executed inside a router). We call this virtual link a *vertical link* (VL), because it can be seen an orthogonal link from a network protocol plane.

Fig. 1 (a) shows an example path in inter-layer 3 networking. In this example, each network is operated by a different network layer protocol. Packets can be transferred to a different network through shared node (P and Q in this example). In Fig. 1 (a), host A operating NW X protocol communicates with host B operating a different protocol, NW Y protocol. In conventional network, a host in NW X cannot communicate with a host in NW Y because protocols of two hosts and thus network layer addresses are different. In ID/Locator separation architecture, host A can identify host B with host ID which is independent of network protocol in use and identical for all hosts. As shown in Fig. 1 (a), a route between host A and B can go through another plane than these two hosts, i.e. NW Z in this example.

For robustness which we are focusing in this paper, inter-layer 3 networking generally has two following positive aspects.

**Roundabout path in another network plane** When a host communicates with another host in a same network plane and a node (router)
along this path is failed, one possible way to recover this communication path is a roundabout path in a single network plane. Without ID/Locator separation architecture and inter-layer 3 networking, this is the only possible way to improve robustness (Fig. 1(b)).

Fig. 1 (c) shows recovery path through another network plane. When a path in NW X plane includes at least two shared nodes (e.g. $S_{1X}$ and $S_{2X}$), a path between two shared nodes in another network protocol plane is a possible roundabout path.

**Roundabout path through multihoming link** When a host has multihoming access links, a roundabout path through it is also a candidate for a roundabout path (Fig. 1(d)). For this roundabout path, only one shared node is necessary for bridging a path towards another plane.

When a node failure happens, shared node $S_{1X}$ transfers a packet towards another network plane NW Y and then a packet is transmitted to a router in NW Y to which destination host B is directly attached via a multihoming access link.

ID/Locator separation architecture and inter-layer 3 networking enable these two additional types of roundabout path, which provide a possibility of robustness with little increase of path length.

### 3 Performance evaluation of robustness for node failure

We evaluate robustness of inter-layer 3 networking by computer simulation. We use 3-network model, where there are 3 network protocol planes (NW1, NW2 and NW3). Each network plane includes 100 routers and totally there are 300 routers in our simulation model. These networks are connected by randomly selected shared nodes. The number of shared nodes (this number is equal to the number of vertical links) is parameter of our simulation. For network topology, random model generated by Waxman graph and BA model generated by BRITE generator are used. Every end host has an access link to NW1 so that it can keep connectivity to all other nodes (NW1 protocol can be observed as IPv4 network, because currently all (or almost) nodes have connectivity to it). Each end host has connectivity to NW2 and NW3 with respective independent probability of 0.5. For a shared node (router) in NW1, 2 and 3, it is selected independently and randomly. Simulation model in this paper is similar to the one used in our previous paper which evaluates path cost improvement [6], so for detailed explanation of our simulation model please refer to it.

Figs. 2(a) and (b) show disconnection rate characteristics of inter-layer 3 networking for random model and BA model, respectively. Disconnection rate is defined as the following equation.

$$\text{Disconnection rate} = \frac{N_{\text{unreachable}}}{N_{\text{total}}},$$

For BA model, we use homogeneous BA and heterogeneous BA models in [6]. Due to space limitation, we just show results obtained only for homogeneous BA model. Results for heterogeneous BA model are similar to results depicted in this paper.
Disconnection rate characteristics

where $N_{unreachable}$ is the number of host pairs having no reachable path, and $N_{total}$ is total number of host pairs. In Fig. 2, performance curves for the case of single node failure and 2 node failure are depicted. $VL = 0$ shows performance without inter-layer 3 networking, where recovery is just tried inside a single network plane.

In the case of node failure, all links attached to this failed node cannot be used. So, node failure has more significant influence than link failure. As shown in Fig. 2, even in this severe condition, disconnection rate is improved gradually with increase of the number of VLs, and almost improvement is brought by the first or second attached VL. Disconnection rate is improved about 50% with the first VL. This means 1 or 2 VLs are sufficient for improvement of robustness even for the case of node failure.

Figs. 3 (a) and (b) show relative frequency distribution of increase of path hop for node pairs. Single node failure case is depicted in this figure. A recovered path generally has larger number of hops and this increase of hops...
is defined as “increase of path hop”. Fig. 3 depicts distribution for paths whose routes are changed by node failure. There are several paths which do not change the number of hops from the shortest path even though their routes are changed. “Increase of path hop=0” shows ratio of these paths. As shown in this figure, increase of path hop is also gradually improved with increase of VLs. Especially for BA model, path hop is greatly improved with incremental growth of VLs. In BA model, a shared node can reach a hub node (a node with large outdegree) with short hops in a transferred network, and another shared node through which a path goes back to an original network plane is reachable with small hop count. So, fraction of roundabout paths with little increase of path length is larger than random model. In real networks which are reported to have power law for outdegree, similar effect of improvement of robustness with little increase of roundabout path is expected.

4 Conclusion

In this paper, robustness for node failure of inter-layer 3 networking in ID/Locator separation architecture is evaluated. Disconnection rate and path hop increase is gradually improved with increase of vertical links (links connecting different network protocol planes). Especially, for disconnection rate, only with 1 or 2 VLs, considerable improvement can be obtained. With our evaluation results for link failure case which we have already reported in our previous paper [7], inter-layer 3 networking can improve robustness significantly with small number of VLs for both of link failure and node failure.

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