OSPF Extension for Expected Capacity Guaranteed Routing with Multipath Transmission Based on Long-term failure prediction

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Outline

- Background
  - Contents Cached Network (CCN)
  - Dedicated Path Protection (DPP)
  - MTBF and failure analysis of network equipment
- Related Works
  - Multi-path provisioning (MPP) protection
  - Expected Capacity Guaranteed Routing (ECGR)
  - Failure Prediction
  - Generalized Multi-protocol label switching (GMPLS)

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- Propose
  Route Allocation Process
  Addition of OSPF format
  ECGR application in multiple layers
  Construction a Proof of Concept (PoC)
- Conclusion

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Background: Contents Cached Network (CCN)

Contents Cached Network (CCN): CCN can cache various data on nodes in the network

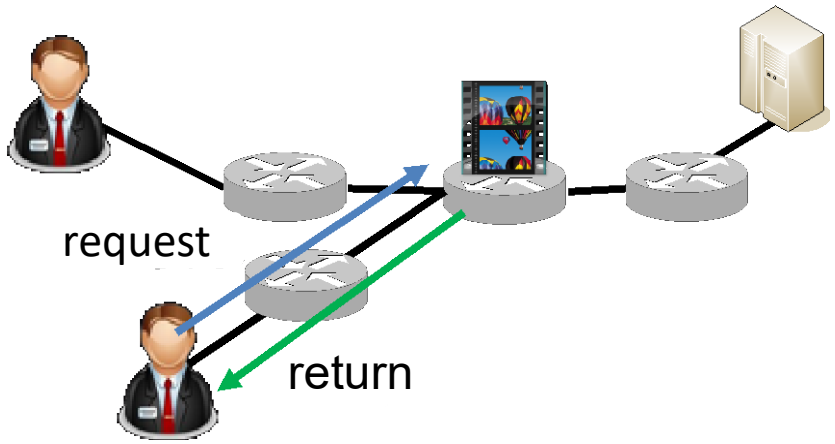


Fig 1. CCN data request and response

The demand and importance of services that transfer various data cashed in the network within the required time with high reliability is increasing.

In order to realize highly reliable transfer, a transfer method that prepares a backup route is used.

= Dedicated Path Protection (DPP)

Background: Dedicated Path Protection (DPP)

Dedicated Path Protection (DPP):
Transfer the same data as the primary path to the backup path, and switch to the backup path if the primary path fails

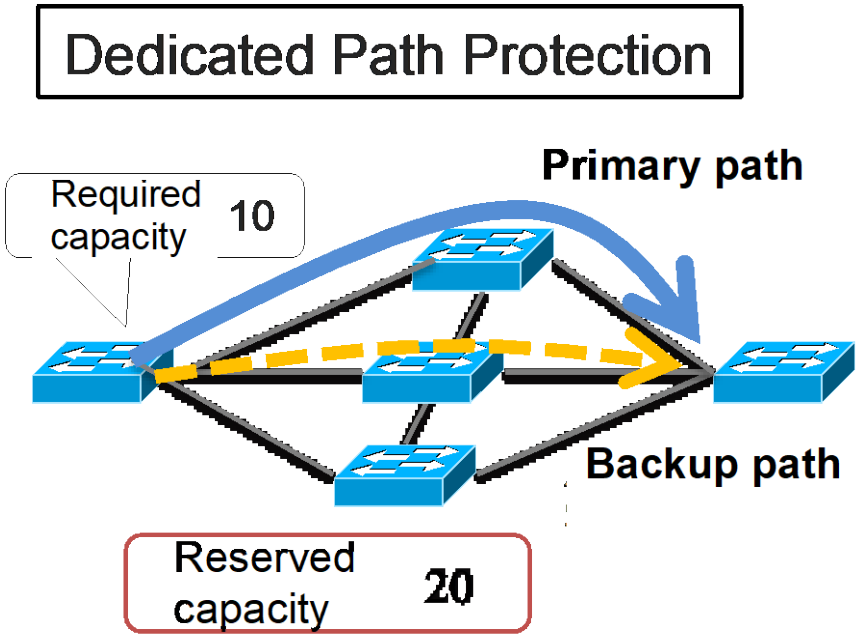


Fig 2. DPP communication example

DPP can maintain communication as long as the main route and backup route do not fail at the same time.

Problem:
Since it is necessary to reserve the same bandwidth for the backup route longer than the main route
→ the utilization efficiency of network resources is low.

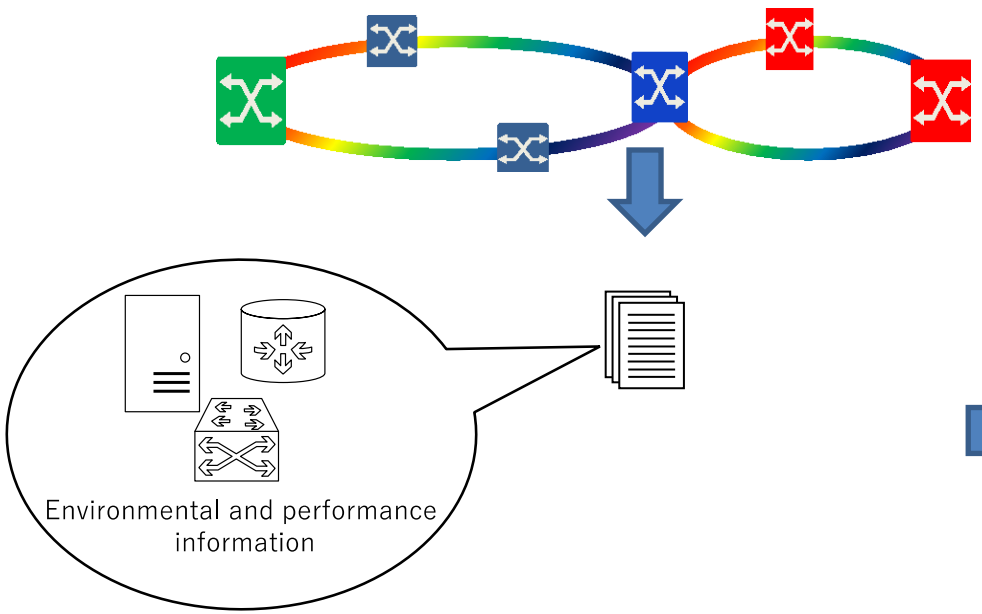
Background: MTBF and failure analysis of network equipment

[1] Y.Uematsu, S.Kamamura, H.Date, H.Yamamoto, A.Fukuda, R.Hayashi, and K.Koda, “Future Nation-Wide Optical Network Architecture for Higher Availability and Operability using Transport SDN Technologies,” IEICE Transactions on Communications, Position Paper, Vol.E101-B, No.2, pp.462-475, 2018

[2] S. Verbrugge, D. Colle, P. Demeester, R. Huelsermann, M. Jaeger, “General availability model for multilayer transport networks,” IEEE DRCN 2005, pp.85-92, 2005

Mean time between failures (MTBF) of network devices is getting shorter with the times [1][2]

The reliability of future networks will be even lower, and multiple failures may occur
= Communication disconnection may occur even with DPP



Environmental information and performance information of the devices that make up the network are collected, and it becomes possible to predict the failure probability.

Expected Capacity Guaranteed Routing (ECGR) was proposed, which incorporates failure prediction into routing and realizes high network resource utilization efficiency and high reliability.

Fig 3. Data collection and failure prediction

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Related Works: Multi-path provisioning (MPP) protection [3]

[3] L. Ruan and Y. Zheng, "Dynamic survivable multipath routing and spectrum allocation in OFDM-based flexible optical networks," in *IEEE/OSA Journal of Optical Communications and Networking*, vol. 6, no. 1, pp. 77-85, Jan. 2014.

Multi-path provisioning (MPP) protection:
Reserve N routes so that the total allocated capacity of all N-1 route pairs exceeds the required capacity

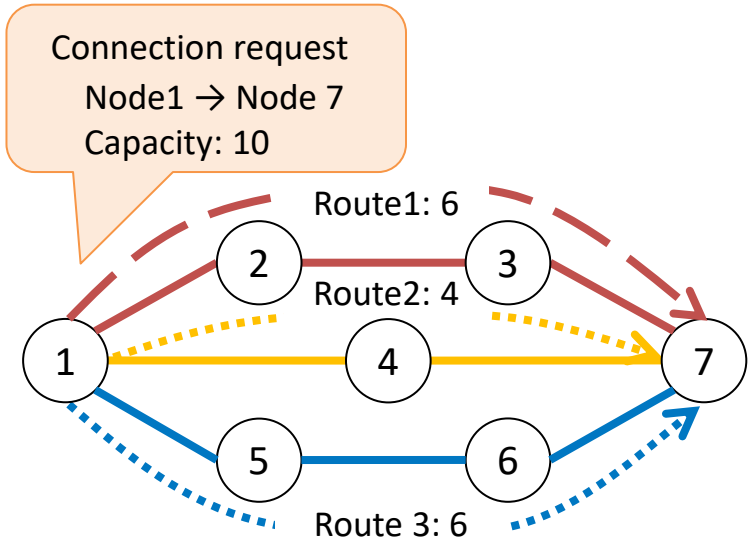


Fig 4. Multi-path provisioning protection setting example

- If there is a 1-link failure, it is possible to recover from the failure
- Achieves higher network utilization efficiency than Dedicated Path Protection, which reserves the active route + backup route by performing multipath allocation.

Efficient traffic accommodation to the network and improved reliability against link failures are achieved by performing multipath routing considering the link failure rate
= Expected Capacity Guaranteed Routing (ECGR)

Related Works: Expected Capacity Guaranteed Routing (ECGR) [4]

[4] S.Sekigawa, E.Oki, T.Sato, S.Okamoto, N.Yamanaka "Expected capacity guaranteed routing method based on failure probability of links" 2017 IEEE International Symposium on Local and Metropolitan Area Networks (LANMAN), pp.1-3, 2017.

Expected Capacity Guaranteed Routing (ECGR):
routing method that reliably transfers the requested amount of data within a required time

Expected capacity: Available probability of route calculated from link failure rate × Allocated capacity

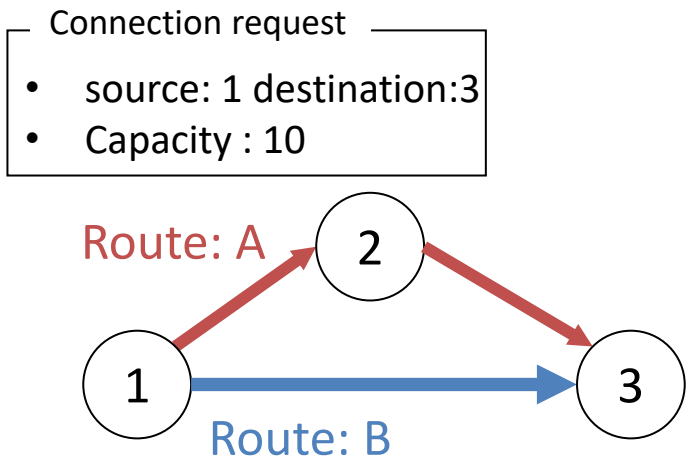


Fig 5. ECGR allocation example

Route A:
Allocated capacity : 6
Available probability : 0.9
Expected capacity = 5.4

Route B:
Allocated capacity : 6
Available probability : 0.8
Expected capacity = 4.8

$$\text{Total Expected capacity} = 10.2 \geq 10$$

- Calculates the expected capacity on each of the allocated paths.
- Selects the multiple paths that the total expected capacity exceeds the requested capacity.

Achieves a high requirement achievement rate regardless of the link failure rate

Related Works: Path Available Probability

- Link Available Probability

  The probability that the link is available during communication.

  Assume that communication starts at T and ends at $T + \Delta t$.

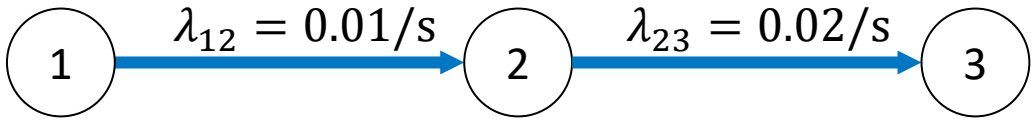
  $$\text{Link Available probability } A_{ij}(T, \Delta t)$$
  $$= P(\text{No failure before } t = T + \Delta t \mid \text{No failure before } t = T)$$
  $$= \frac{R_{ij}(T + \Delta t)}{R_{ij}(T)}$$

- Path Available Probability

  A path can be considered as serial system composed of links.

  ⇨ $\text{Path Available probability} = \prod^{\text{All links}} \text{Link Available probability}$

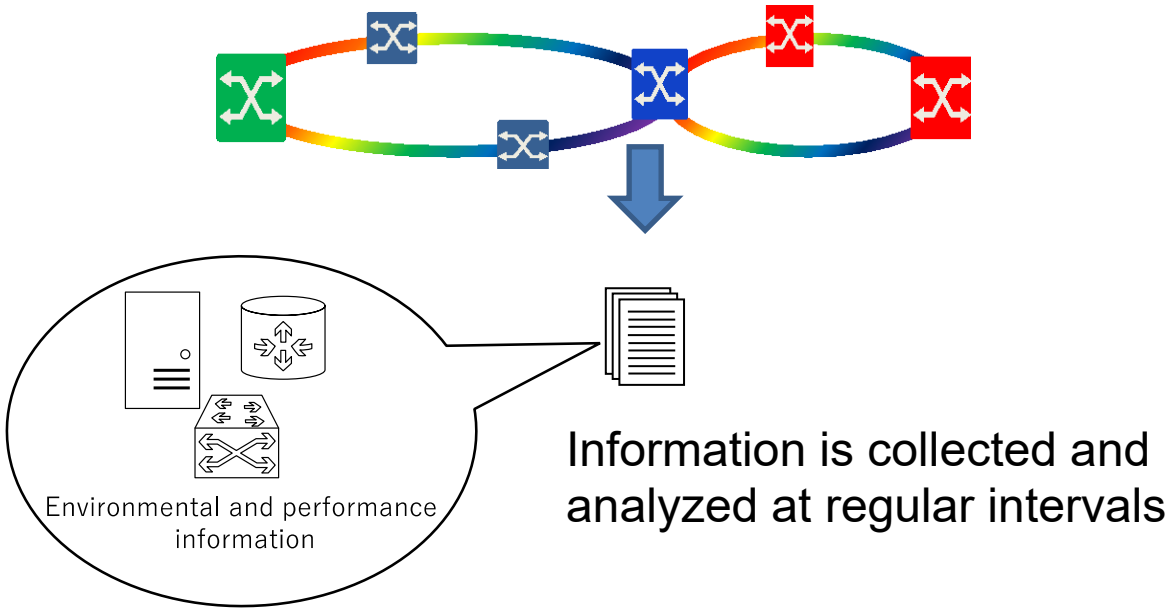
ex) Paths from node 1 to node 3, Connection holding time: $3s$



$$A_{1-2-3}(0,3) = \frac{R_{12}(3)}{R_{12}(0)} \times \frac{R_{23}(3)}{R_{23}(0)} = 0.97 \times 0.94 = 0.91$$

Related Works: Failure Prediction (1 / 2)

[5]G. S. Mudholkar and D. K. Srivastava, "Exponentiated Weibull family for analyzing bathtub failure-rate data," in *IEEE Transactions on Reliability*, vol. 42, no. 2, pp. 299-302, Jun 1993.

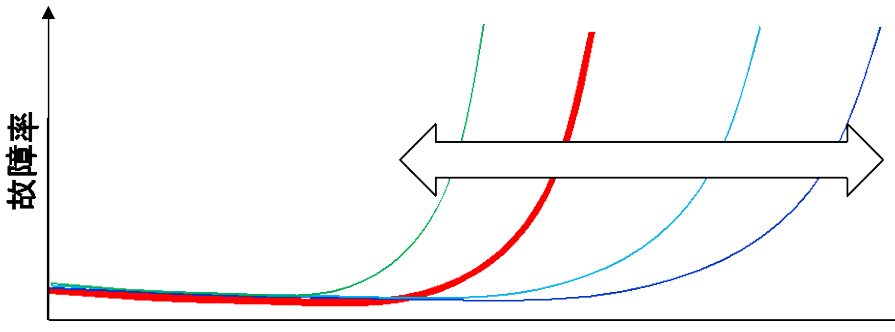


Information is collected and analyzed at regular intervals

Fig 3. Data collection and failure prediction [Repost]

It is assumed that the conventional derivation of failure probability follows the Weibull distribution [5] representing wear failure

Estimate the most likely Weibull distribution parameters (shape, scale) from the collected information



Determine curve parameters for individual devices

Fig 6. Weibull distribution of analyzed network equipment

Related Works: Failure Prediction (2 / 2)

Failure probability estimation using Bayesian estimation:
It is assumed that the true values of the Weibull distribution shape parameters and scale parameters exist for each device that composes the network.

purpose: to bring the value closer to the true value using observation data

Bayesian model formula

$$\pi(\theta|\xi) = \frac{\mathcal{L}(\theta|\zeta)\pi(\theta)}{\int_{\Theta} \mathcal{L}(\theta|\xi)\pi(\theta)d\theta}$$

$\pi(\theta)$: Prior probability density function
$\pi(\theta|\xi)$: Posterior probability density function
$\mathcal{L}(\theta|\zeta)$: Likelihood function

The distribution of θ changes according to the observation data

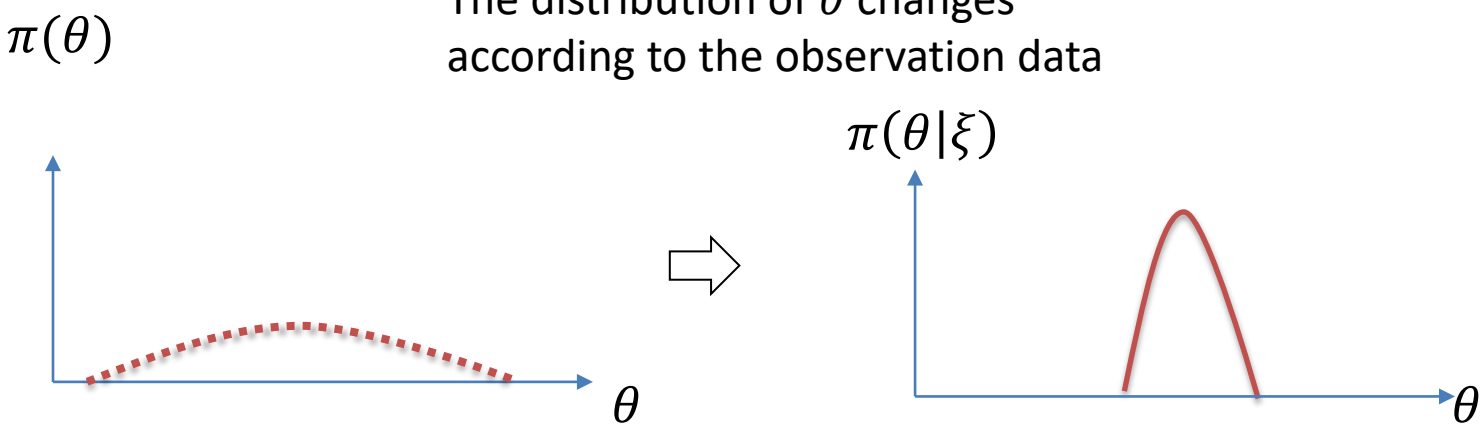


Fig 7. Distribution update

Related Works: Generalized Multi-protocol label switching (GMPLS)

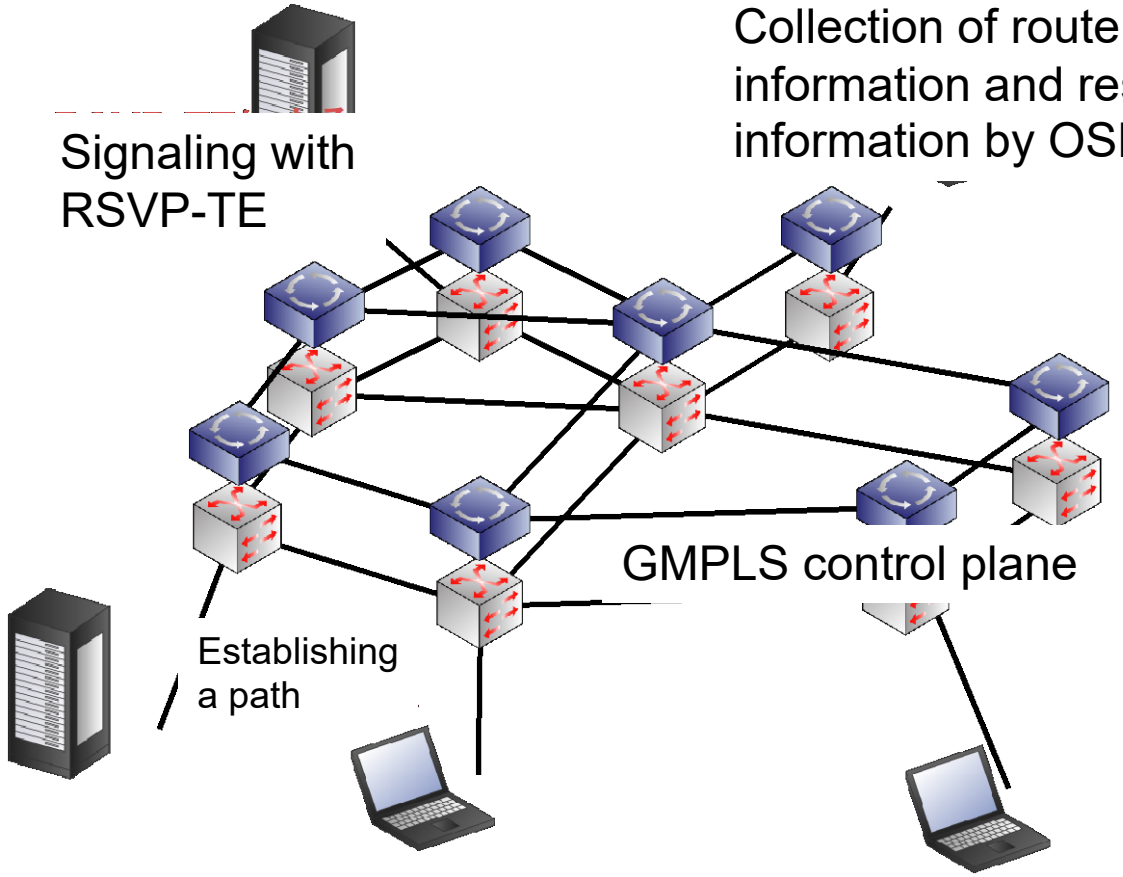


Fig 8. GMPLS concept

- Next-generation protocols that realize automation of communication path (Path) establishment to networks of various layers

- OSPF-TE (routing) Collect resource information such as mutual switch and route information, bandwidth information, and VLAN ID
- RSVP-TE (Signaling) Resource reservation for path establishment
- On demand path can be established according to user's request

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Propose: Route Allocation Process

1. Connection request $r =< p, q, B_{req}, t >$ occurs.
   p: Source node, q: Destination node,
   B_{req}: Expected Capacity requirement, t: Connection holding time
2. Calculates the Link Available probability from Link failure rate.
3. Solves K-shortest path and selects the paths and allocated capacity.

ECGR needs to share parameters of Weibull distribution to explain failure

Stored in TLV of OSPF Opaque LSA for transmission and sharing

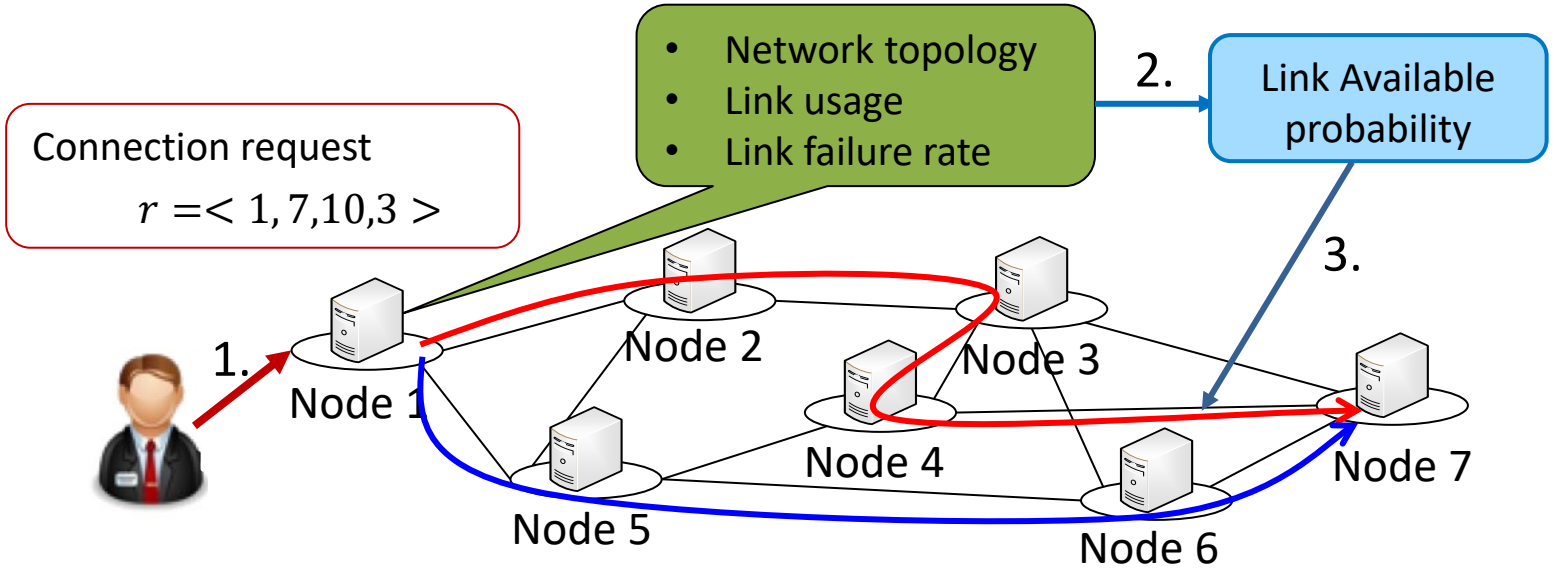


Fig 9. ECGR operation on the GMPLS control plane

Propose: Addition of OSPF format

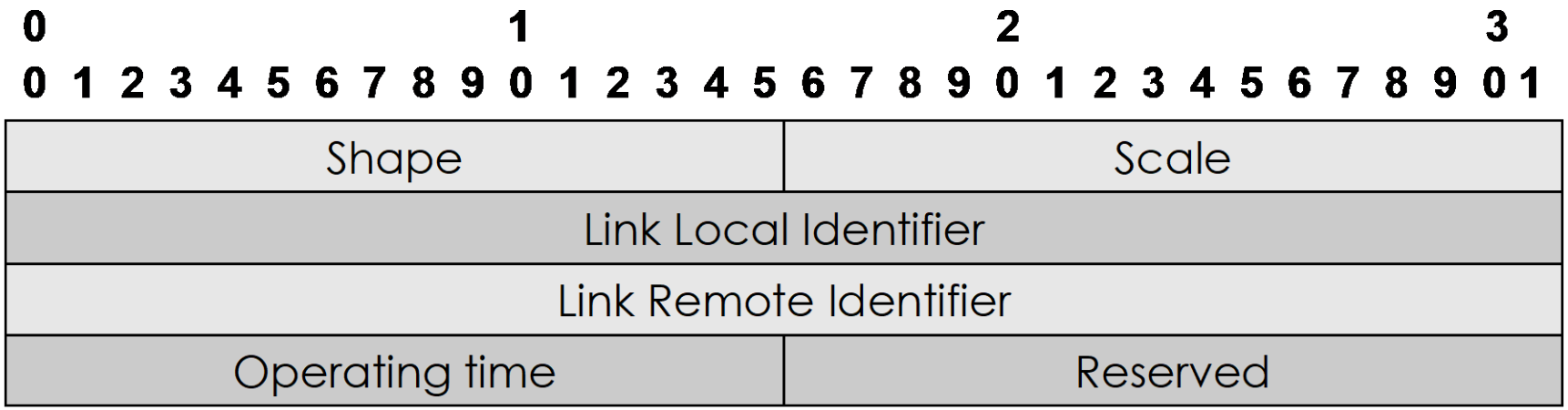
Purpose: In ECGR, it is necessary to share the information because the route calculation is performed using the failure information of the equipment.

Method: Stored in TLV of OSPF Opaque LSA for transmission and sharing

Sub-TLV Type	name	value	remarks
17	Failure Prediction	32	

Parameters (shape, scale), time of use (day), link ID that explain the failure probability density function of each link

Fixed length



Propose: ECGR application in multiple layers

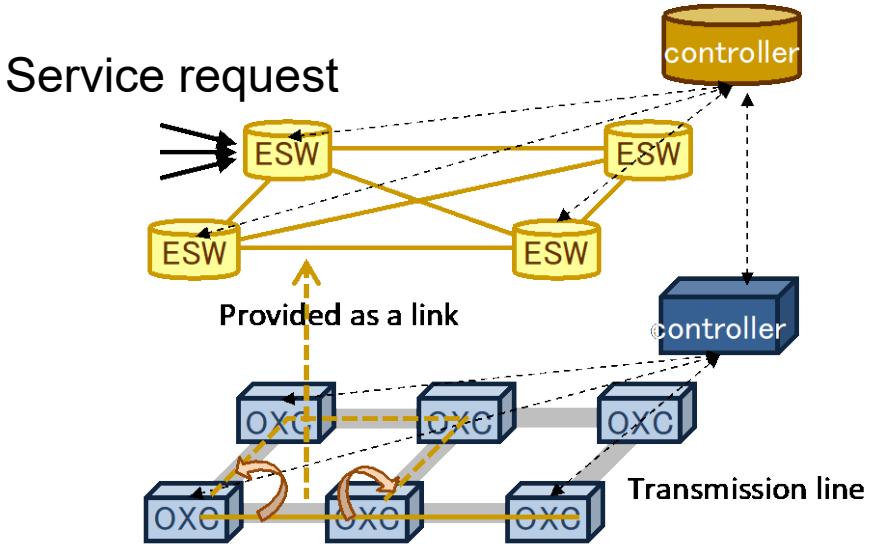
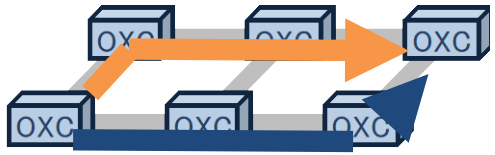


Fig 9. ECGR in multi layer

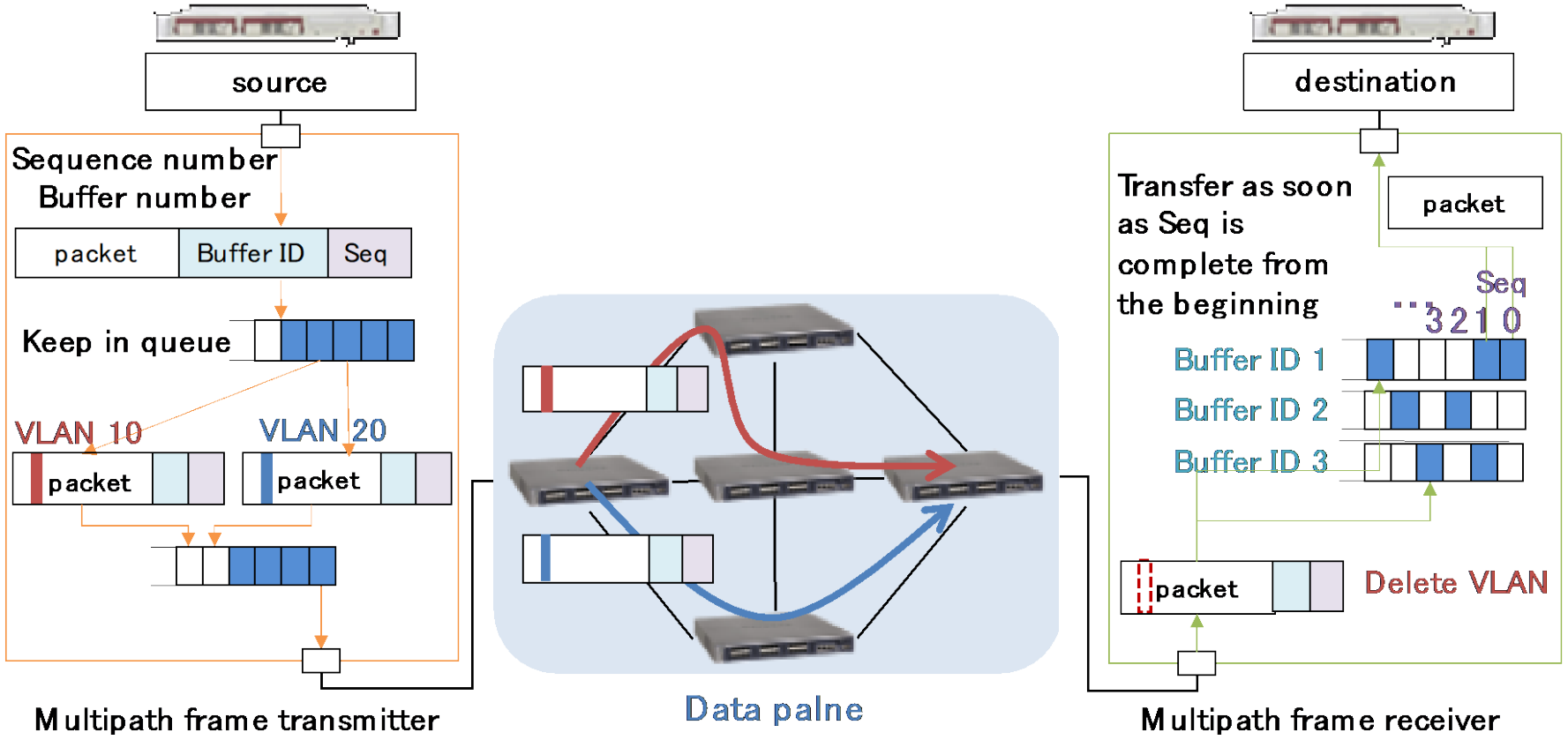


When providing a backup path at a lower layer, it is generally reserved by a disjoint route.

ECGR can provide highly reliable paths by incorporating dependency establishment into route calculation even for partially connected paths

= Provides a highly reliable and low blocking rate path

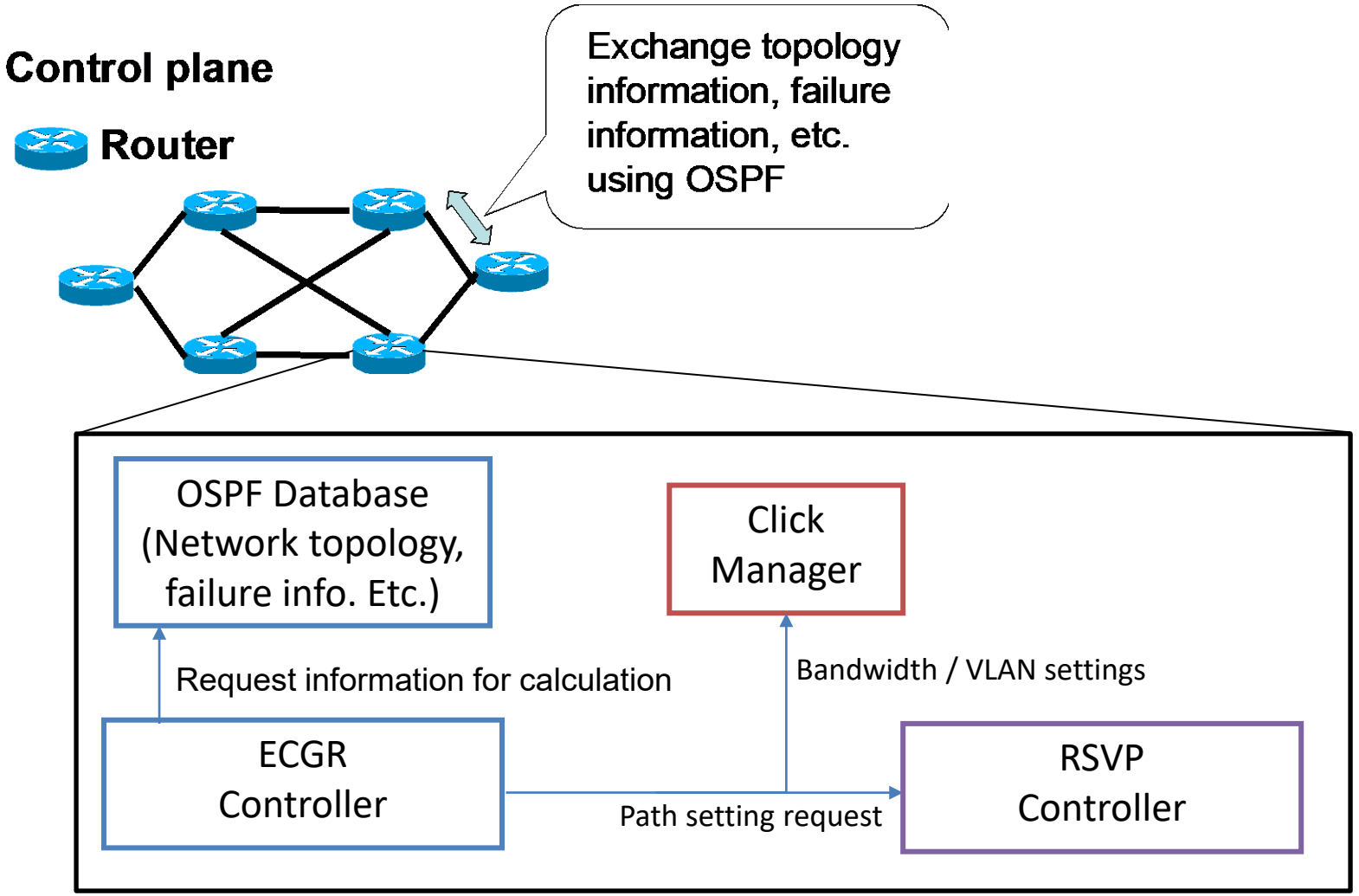
Propose:Construction a Proof of Concept (PoC) (1 / 2)



In data plane,
Guaranteed packet arrival order with multipath frame transmitter / receiver

Fig 10. Multipath transfer function implementation overview diagram

Propose:Construction a Proof of Concept (PoC) (2 / 2)



・In the control plane, the ECGR controller uses OSPF-extended data and topology information to calculate the path.

・Execute route reservation with RSVP to paste the calculated path

・Command click manager to configure multipath transferer / receiver

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Conclusion

Background

- The demand and importance of services that transfer various data accumulated in the network within the required time with high reliability is increasing.
- A highly reliable routing method is required to support MTBF of network equipment that becomes shorter with the times.
- It becomes possible to predict the failure probability.

Related works

- ECGR was proposed that incorporates failure into the routing method

Proposed approach

- Define an OSPF extension format to apply ECGR on GMPLS
- Proposed the effectiveness of ECGR in multiple layers

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Thank you for listening

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