Analysis of Signaling in GMPLS-Based WSONs: Distributed Wavelength Assignment in Bidirectional Lightpath Provisioning

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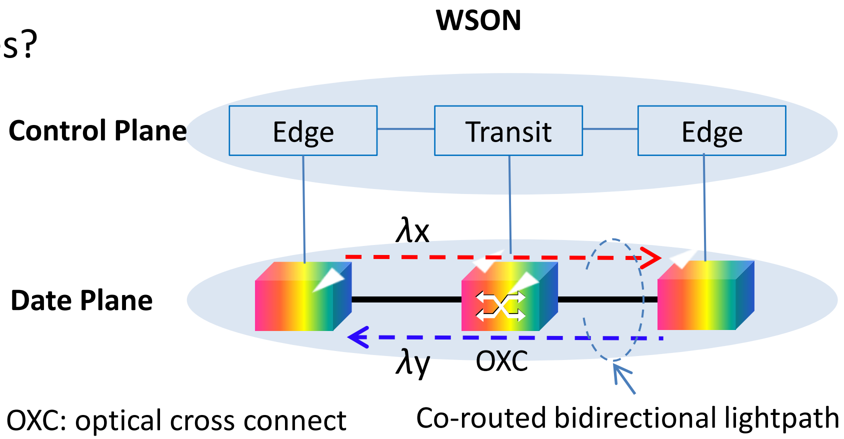
Outlines

- Introduction
- Requirement for enhancing distributed wavelength assignment (WA) support with signaling
- Performance measures and selected Findings
- Some constraints in consideration
- Candidates of distributed WA approaches
- Numerical results
- Summary

Introduction

- Lightpath services in wavelength switched optical network (WSON)
  - Unidirectional lightpath
  - Bi-directional lightpath
- Current topics in IETF: extensions of GMPLS for better WSON support
- Focus of this talk:
  - Efficient Signaling support for distributed wavelength assignment (WA) in the GMPLS-based control plane of WSON
  - Co-routed bi-directional LSP provisioning support, per *RFC 3945, RFC 3473*
  - Is the current standard RSVP-TE per *RFC 3473* enough?
    - What perspective can be improved further?
    - Any other cost-efficient signaling schemes?
  - Conduct protocol analysis and share the findings
- Out of the scope of this talk (other perspectives)
  - Physical impairment concern
  - 3R concern
  - Wavelength conversion concern



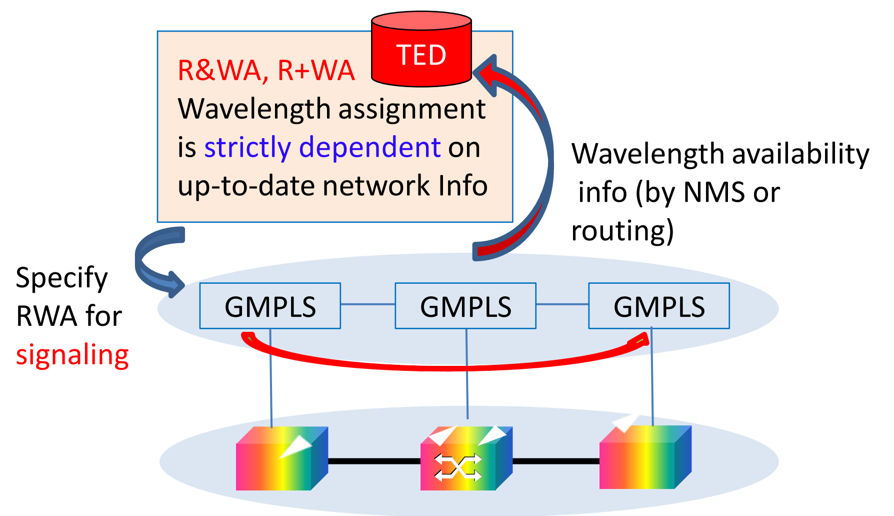
Architectures for Co-Routed Bi-directional Lightpath Provisioning

cf) *RFC 6163*

Architecture Categories:

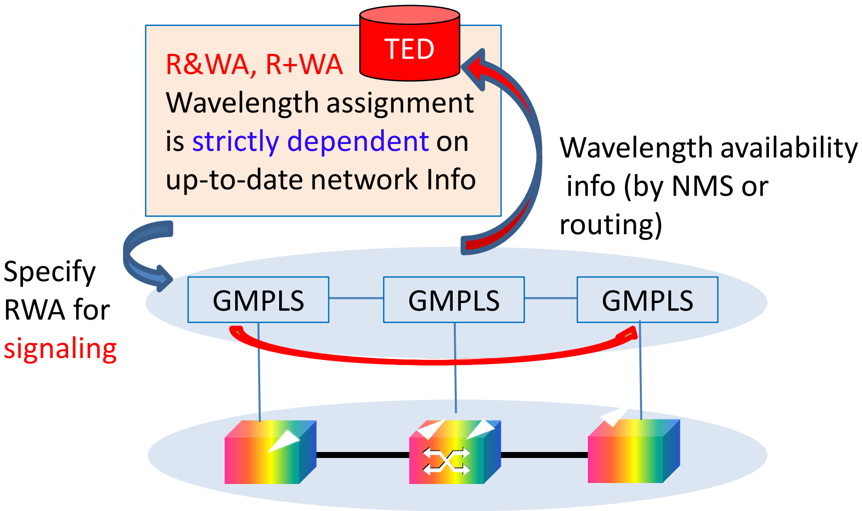
1. Combined RWA (R&WA) computation + Signaling
2. Separated RWA (R+WA) computation + Signaling
3. Routing + Signaling-based distributed wavelength assignment (R+DWA)

- Three phases in R&WA and R+WA architectures
  - Routing (or NMS) collects the up-to-date wavelength availability information
  - PCE, or C-SPF performs RWA calculation
  - A simple signaling performs the wavelength allocation which is specified by RWA optimization



Current standard RSVP-TE is applicable in R&WA, R+WA modes
(Single RWA solution: specify **one** wavelength in the Upstream Label obj, per *RFC 3471, RFC 3473)*

R&WA and R+WA WSONs Also Needs Robust Distributed WA Support with Signaling



- RSVP-TE only supports single RWA solution specification
- feasible WA solution highly depends on the up-to-date info
- acquiring the up-to-date info leads to the increased information dissemination, resulting in heavy load in control plane

- Restrict the scalability of WSON
- Limit the possibility for **dynamic lightpath** service in WSON

Needs robust Distributed WA support with Signaling (**not highly relying on up-to-date info**)

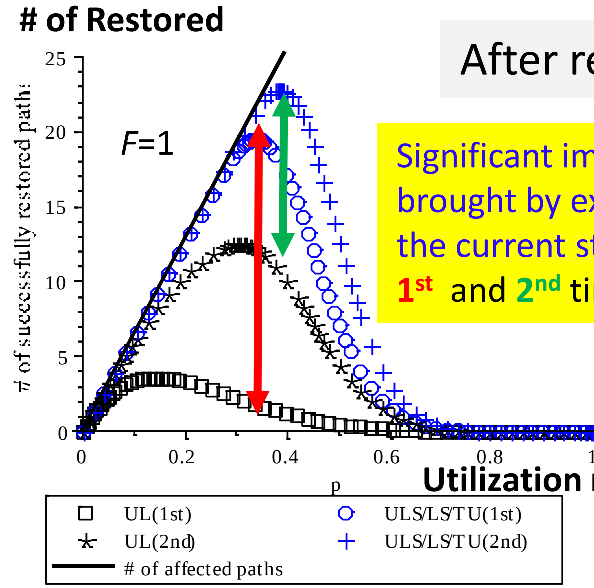
- Already standardized novel DWA mechanisms in *RFC 3471, 3473*
  - Unidirectional lightpath ○
    - Label Set obj **CAN** convey the **multiple** wavelengths (labels) assignment solutions in the downstream direction (Increasing the possibility of successful lightpath provisioning)
  - **Bidirectional lightpath with Upstream Label (UL) ?**
    - Upstream Label obj conveys **only one** specified wavelength in the upstream direction
    - Acceptable Label Set conveys the available wavelengths in case the upstream label in the Upstream Label obj is blocked
      - **Relies on crank-back (a second time signaling)**

Any other possibilities to provide more cost-efficient **bidirectional lightpath provisioning**?

Performance Measures and Selected Findings’ Highlight

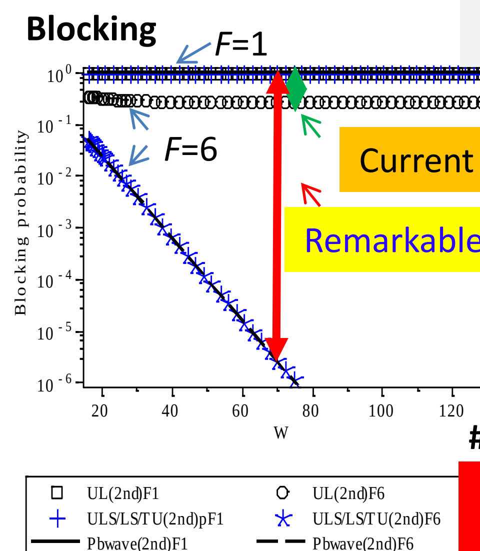
What measures do we use in signaling evaluation?

- Blocking performance (efficiency measure)
  - Single lightpath
  - Multiple lightpaths Restoration
    - Number of the successfully re-established lightpaths by signaling (with evenly distributed re-routing)
  - Long-term view of performance potential (future-proof signaling solution)
    - Upgrade WSON with more wavelengths, fibers
- Protocol cost (cost measure)
  - Total number of traversed Hops in one set of signaling
  - Accumulated label-processing “times”



After restoration

Significant improvement brought by extensions of the current standard 1st and 2nd time signaling



After upgrading

Current standard’s gain

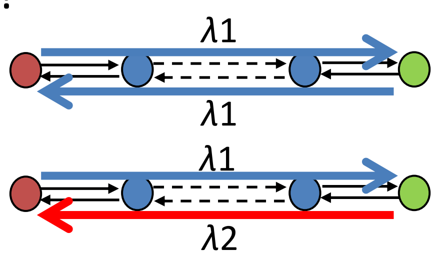
Remarkable gain of extensions

# of Wavelengths

High utilization rate *p*=0.8

Constraint Concerns in Protocol Behavior Analysis

- CI-Incapable
- Co-routed bi-directional lightpath
- Is it necessary to use the same wavelength in both directions?
  - Yes. Either initiator or terminator are the colored edge (with the port/wavelength restriction at edges)
  - No. Both initiator and terminator are the colorless edge

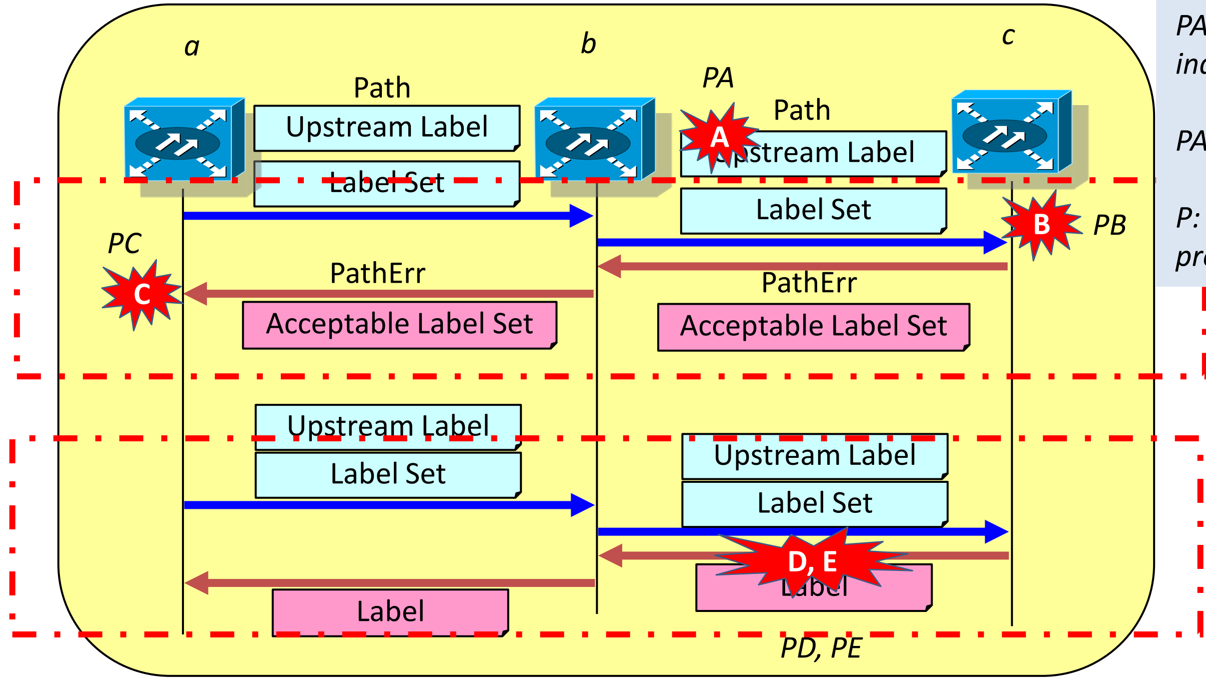


Initiator \ Terminator	Colored edge	Colorless edge
Colored edge	Same wavelength use	Same wavelength use
Colorless edge	Same wavelength use	Different wavelengths use

Scenarios and corresponding Signaling candidate schemes

- Same wavelength use scenario
  - UL, ULS, TU, LS
- Different wavelengths use scenario
  - UL, ULS, TU

Upstream Label Approach (UL) *RFC 3473* 's Behavior
- Needs 2nd Time Signaling (Crank-back) (Same Wavelength Use)



PA~PE: Probabilities of individual cases

PA+PB+PC+PD+PE=P

P: total blocking probability

Different blocking situations in 1st time signaling result in different blocking probability in 2nd time signaling

Blocking situations in UL (1st time signaling)

Forward blocking

A: The specified upstream label has been occupied by other lightpath

B: The specified upstream label is not appeared in final Label Set (cannot use the same wavelength)

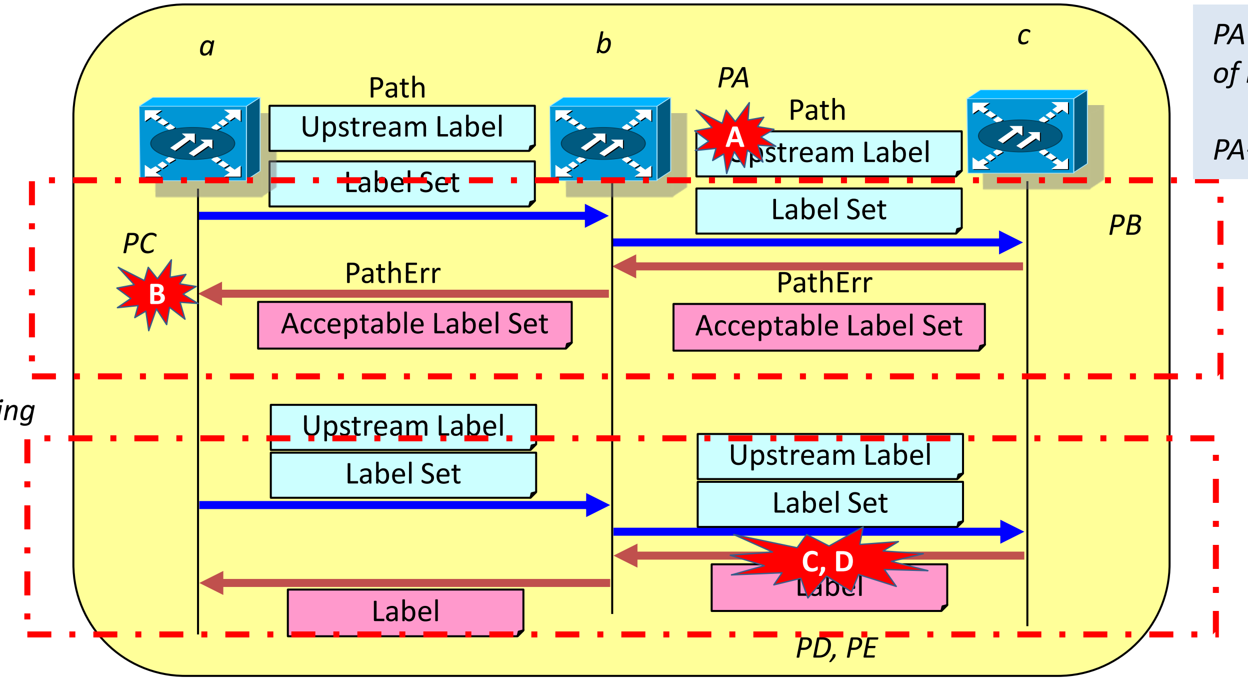
C: Initiator receives an empty Acceptable Label Set, indicating that no wavelength is available along this path, resulting in rerouting

Backward blocking

D: Upstream label is successfully reserved in the upstream direction, and is in Label Set (available in downstream), however, the label is firstly reserved by other concurrent competitive lightpath request. This label happens to be the last available wavelength. No support in RSVP-TE per RFC 3473 can indicate this situation, resulting in useless crank-back

E: Similar to ***D***, but there still are other available wavelengths

Upstream Label Approach (UL) *RFC 3473*'s Behavior
- Needs 2nd Time Signaling (Crank-back) (Diff Wavelength User)



PA~PD: Probabilities of individual cases

PA+PB+PC+PD=P

Different blocking situations in 1st time signaling result in different blocking probability in 2nd time signaling

Blocking situations in UL (1st time signaling)

Forward blocking

A: The specified upstream label has been occupied by other lightpath

B: Initiator receives an empty Acceptable Label Set, indicating that no wavelength is available along this path, resulting in rerouting

Backward blocking

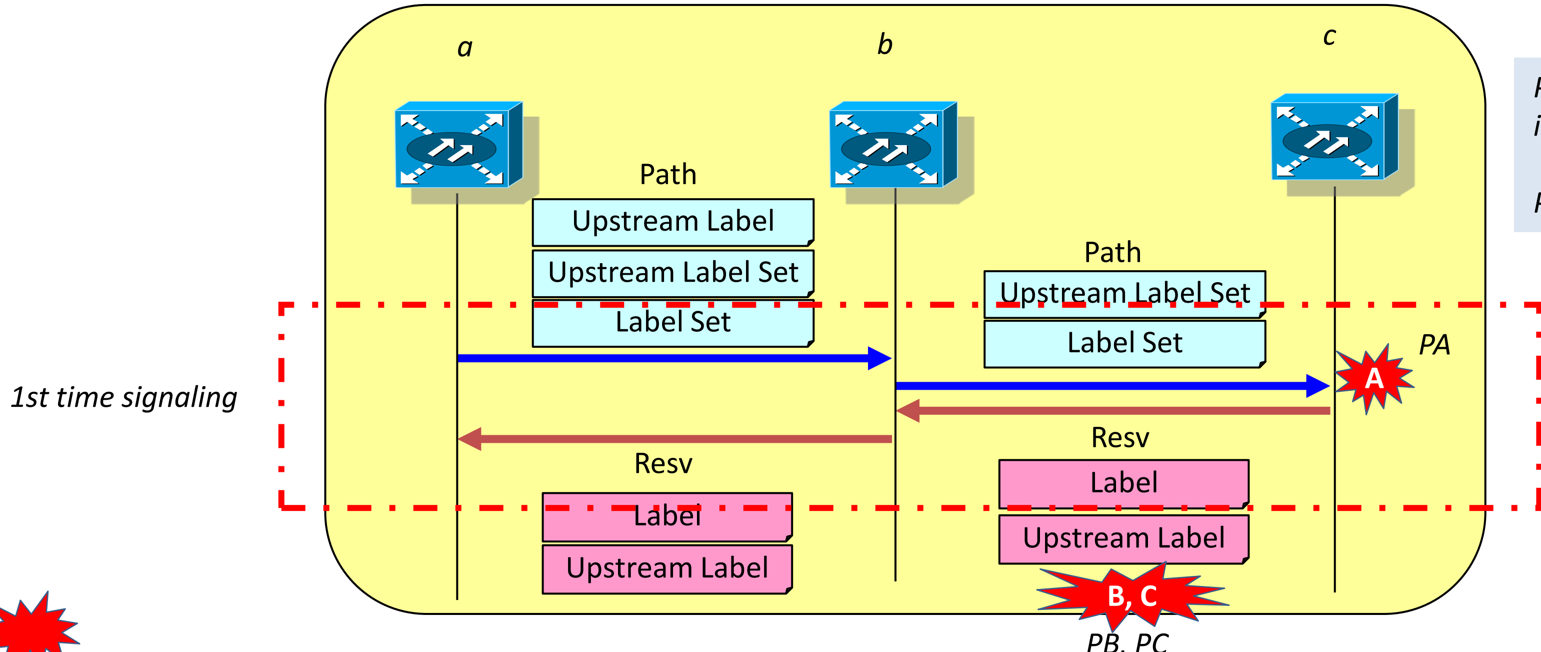
C: upstream label is successfully reserved in the upstream direction, and Label Set (available in downstream) is not empty, however, the label (downstream) is firstly reserved by other concurrent competitive lightpath request

This label happens to be the last available wavelength (a rare case)

D: Similar to ***C***, but there still are other available wavelengths

Upstream Label Set Approach (ULS)'s Behavior (Same Wavelength Use)

cf) E. Oki et al., vol.E87-B, no.6, June 2004.



PA~PC: Probabilities of individual cases

PA+PB+PC=P

Different blocking situations in 1st time signaling result in different blocking probability in 2nd time signaling

Blocking situations in ULS (1st time signaling)

Forward blocking

A: There is not any common wavelength in Upstream Label Set and Label Set at terminator. <u>This includes the situation which either Label Set obj is empty during the Path message processing</u>

Backward blocking

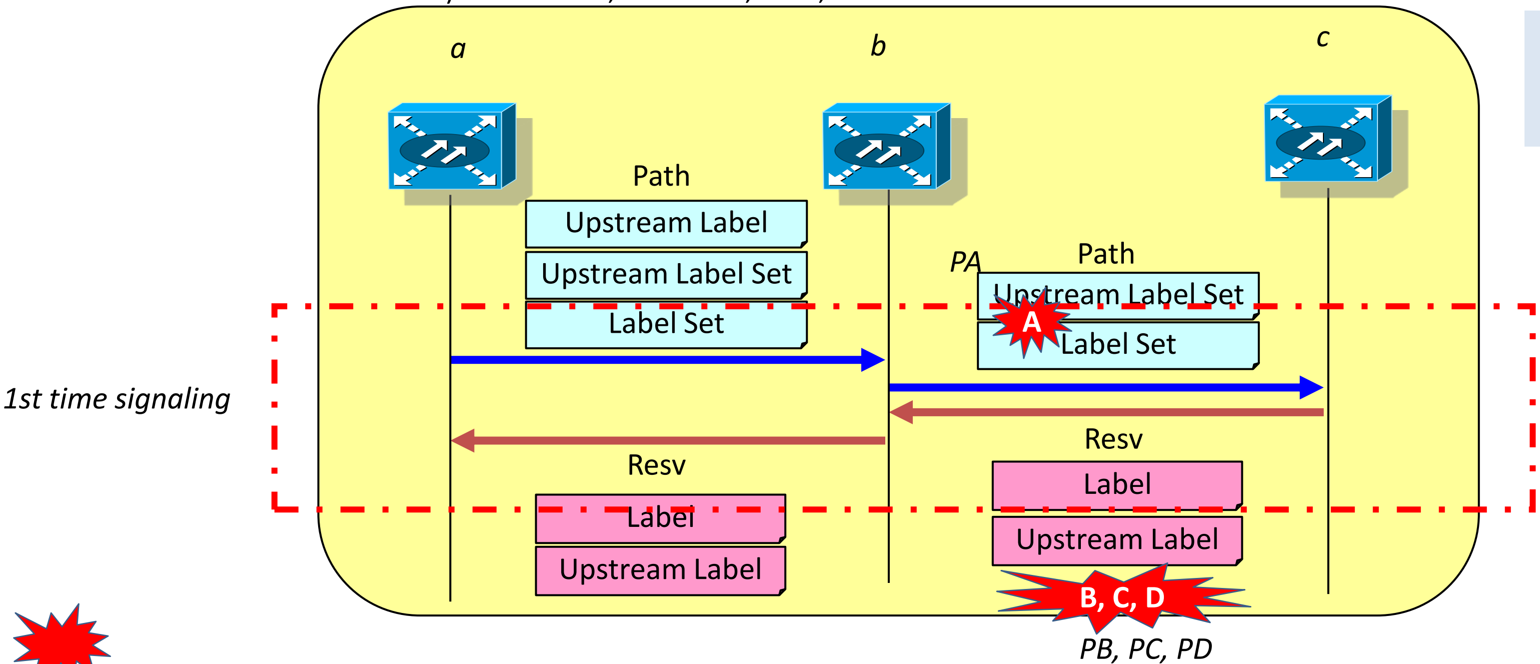
B: Upstream label (upstream) or label (downstream) is firstly reserved by other concurrent competitive lightpath request. This label happens to be the last available wavelength (a rare case)

C: Similar to ***B***, but there still are other available wavelengths

We **can extend ULS** by adding a new object to inform the initiator <u>the number of available wavelengths. Initiator can correctly decide if a **new route** should be employed, in case no wavelength is available.</u>

Upstream Label Set Approach (ULS)'s Behavior (Diff Wavelength Use)

cf) E. Oki et al., vol.E87-B, no.6, June 2004.



PA~PD: Probabilities of individual cases
PA+PB+PC+PD=P

Different blocking situations in 1st time signaling result in different blocking probability in 2nd time signaling

Blocking situations in ULS (1st time signaling)

Forward blocking

A: There is not any wavelength in either Upstream Label Set or Label Set

Backward blocking

B: Either upstream label (upstream) or label (downstream) is firstly reserved by other concurrent competitive lightpath request. This label happens to be the last available wavelength (a rare case)

C: Both upstream label (upstream) and label (downstream) are blocked by other concurrent competitive lightpath request(s), but there are other available wavelengths left to use

D: One direction is blocked, the other direction is not blocked, but there are other available wavelength to use

We **can extend ULS** by adding a new object to inform the initiator the number of available wavelengths.

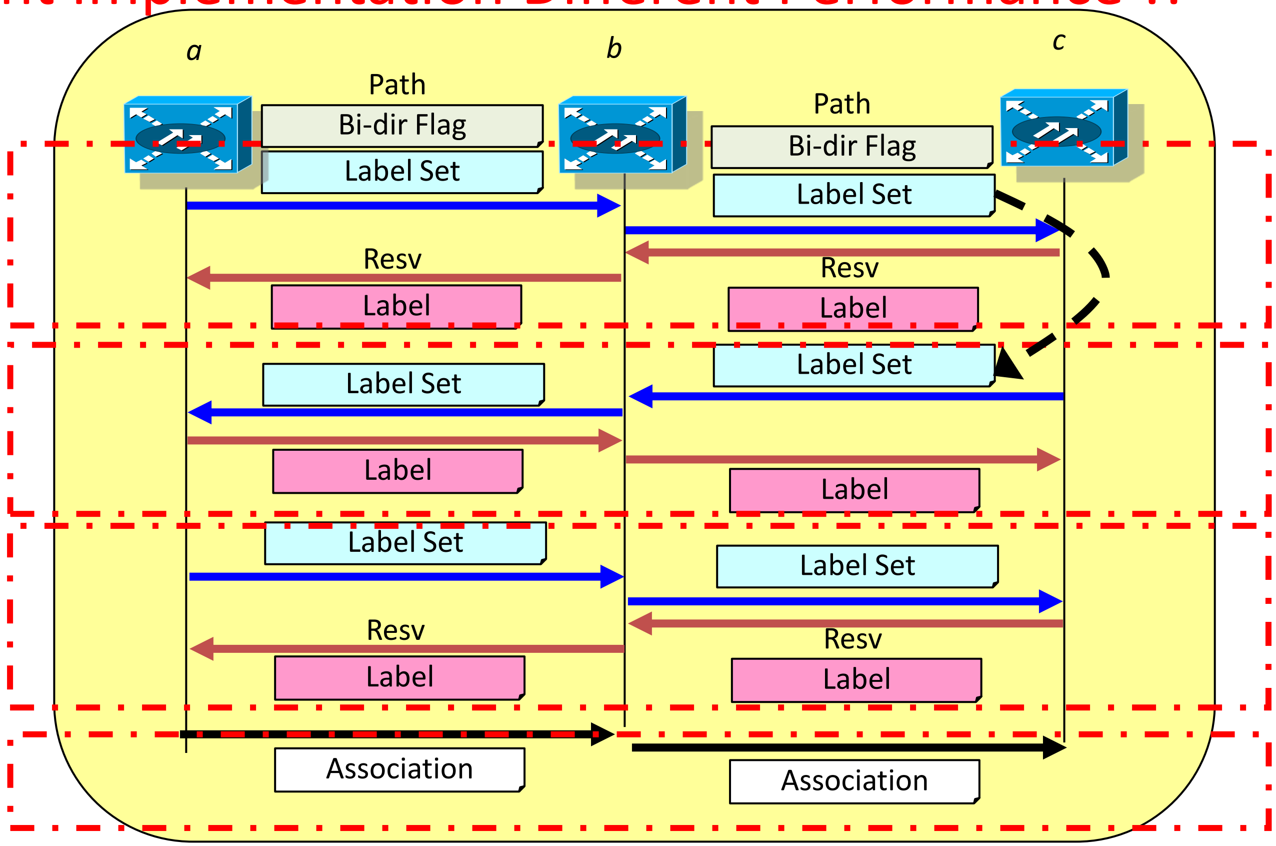
⇩

Initiator can correctly decide if a new route should be tried, in case no wavelength is available.

Two Unidirectional Lightpaths Approach (TU) 's Behavior (One set signaling for two directions)

Different Implementation Different Performance !!

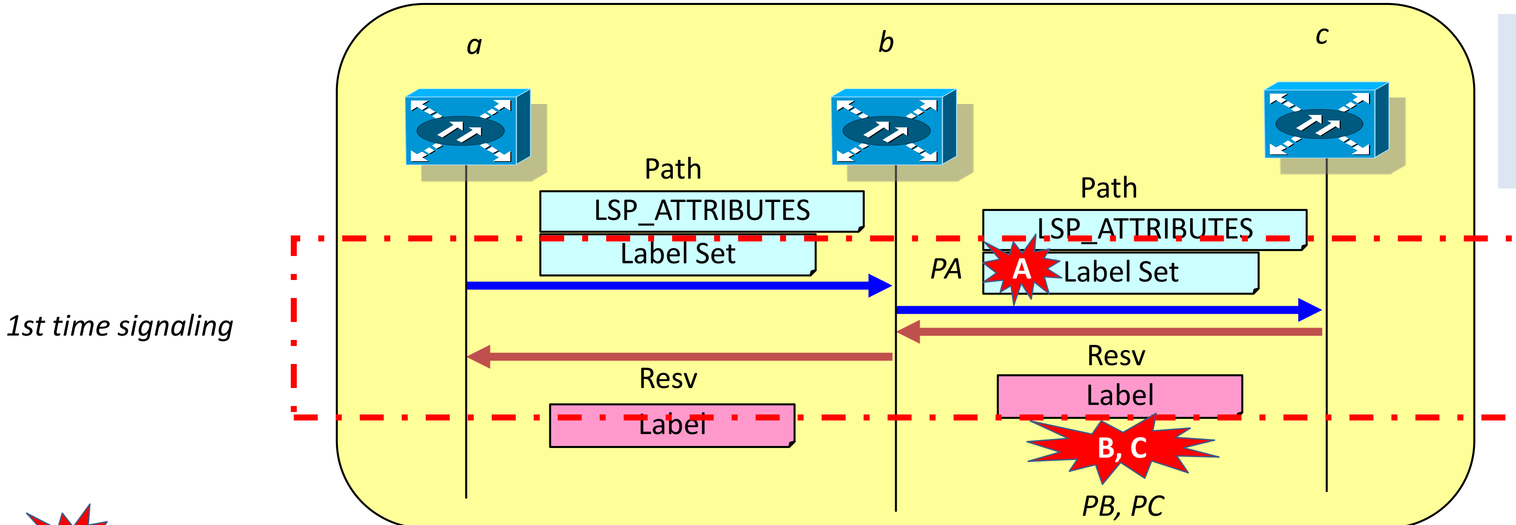
Example



Because TU is of the **most flexibility** in implementation, in principle, in both "Same Wavelength Use" and "Different Wavelength Use" scenarios,
TU may reach the same blocking level as that of ULS

Label Set + LSP_ATTRIBUTES Approach (LS)'s Behavior (Same Wavelength Use Only)

cf) G. Bernstein et al., "draft-ietf-ccamp-wson-signaling-01.txt"



PA~PC: Probabilities of individual cases

PA+PB+PC=P

Different blocking situations in 1st time signaling result in different blocking probability in 2nd time signaling

Blocking situations in LS (1st time signaling)

Forward blocking

A: There is not any wavelength in Label Set

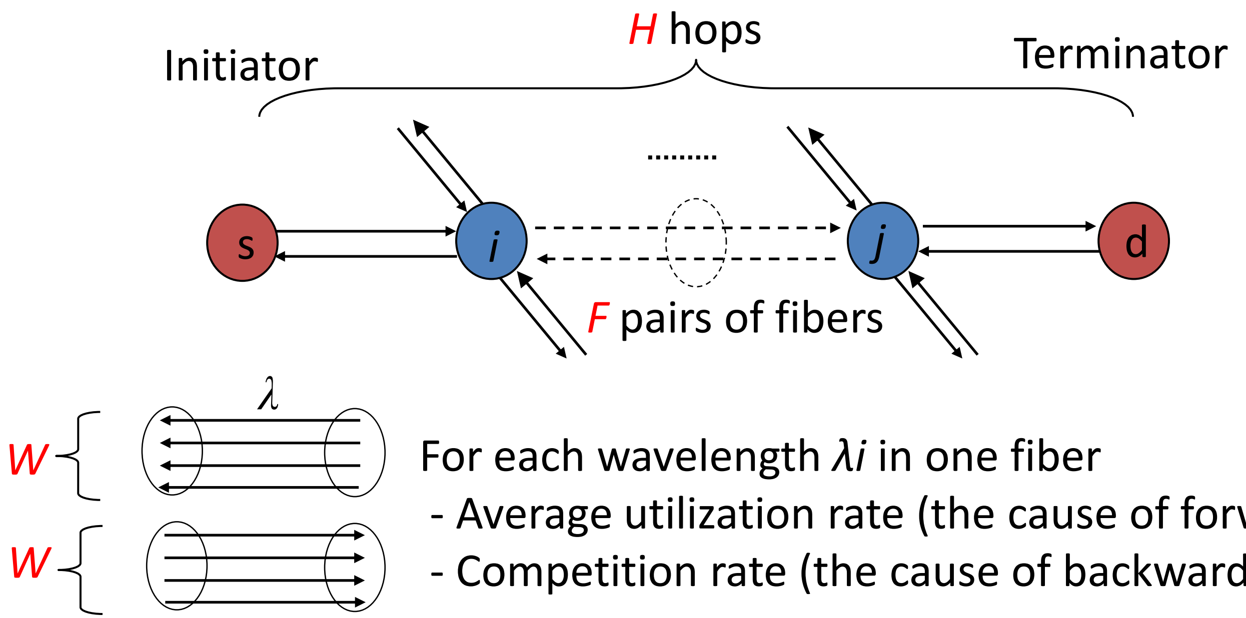
Backward blocking

B: Upstream label (upstream) or label (downstream) is firstly reserved by other concurrent competitive lightpath request. This label happens to be the last available wavelength (a rare case)

C: Similar to ***B***, but there still are other available wavelengths

We **can extend LS** by adding a new object to inform the initiator the number of available wavelengths. Initiator can correctly decide if a new route should be tried, in case no wavelength is available.

Network Model



For each wavelength λi in one fiber

- Average utilization rate (the cause of forward blocking): *p*
- Competition rate (the cause of backward blocking): *b*

Exist available disjoined route in case of rerouting

Blocking probability *P* is the function of *p*, *b*, *H*, *F*, *W*. *P*(*p, b, H, F, W*)

Probabilistic Analysis—Blocking Probability (1st Time Signaling)

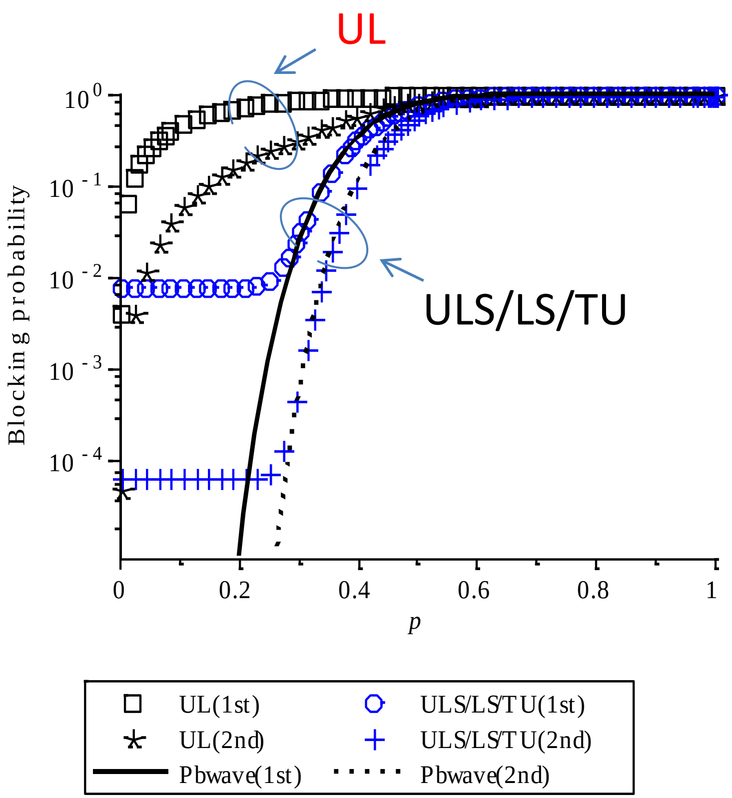
2nd Time Signaling (crank-back) Analysis is not shown here, due to time limitation. Please refer to Proc.

Scenarios / Approaches	**Same Wavelength Use**	**Different Wavelength Use**
1) UL **Upstream Label** **+ Acceptable Label Set**	$P_b(p,H,F,W,b)=\left(1-\left(1-\left(1-\left(1-p^F\right)^2\right)^W\right)\cdot\left(1-p^F\right)^{2\cdot(H-1)}\cdot\left(1-b^F\right)^H\right)$	$P_b(p,H,F,W,b)=1-\left(1-p^{F\cdot W}\right)\cdot\left(1-p^F\right)^{H-1}\cdot\left(1-\left(1-\left(1-p^F\right)^H\right)^W\right)\cdot\left(1-b^F\right)^H$
2) TU **Associated two uni-LSPs**	$P_b(p,H,F,W,b)=\left(1-\left(1-\left(1-\left(1-p^F\right)^{2\cdot H}\right)^W\right)\cdot\left(1-b^F\right)^{2\cdot H}\right)$	$P_b(p,H,F,W,b)=1-\left(1-\left(1-\left(1-p^F\right)^H\right)^W\right)^2\cdot\left(1-b^F\right)^{2\cdot H}$
3) ULS **Upstream Label Set** **+ Label Set**	$P_b(p,H,F,W,b)=\left(1-\left(1-\left(1-\left(1-p^F\right)^{2\cdot H}\right)^W\right)\cdot\left(1-b^F\right)^{2\cdot H}\right)$	$P_b(p,H,F,W,b)=1-\left(1-\left(1-\left(1-p^F\right)^H\right)^W\right)^2\cdot\left(1-b^F\right)^{2\cdot H}$
4) LS **Label Set** **+LSP_ATTRIBUTES**	$P_b(p,H,F,W,b)=\left(1-\left(1-\left(1-\left(1-p^F\right)^{2\cdot H}\right)^W\right)\cdot\left(1-b^F\right)^{2\cdot H}\right)$	not support

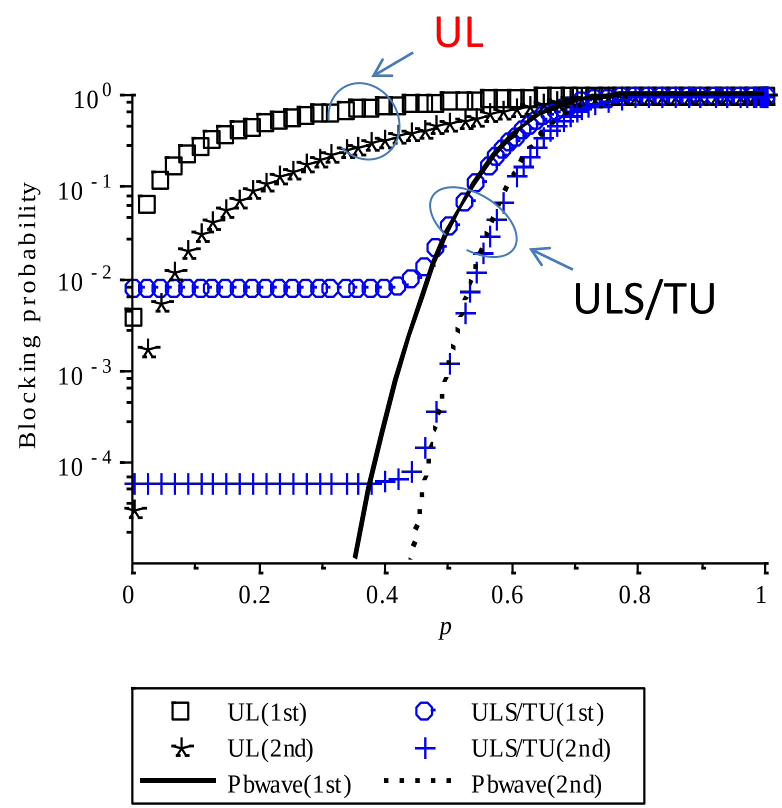
H : number of hops *W* : number of wavelengths *F*: number of fibers

p: wavelength utilization rate per fiber link *b*: competition rate

Blocking Probabilities after the 1st and 2nd Signaling



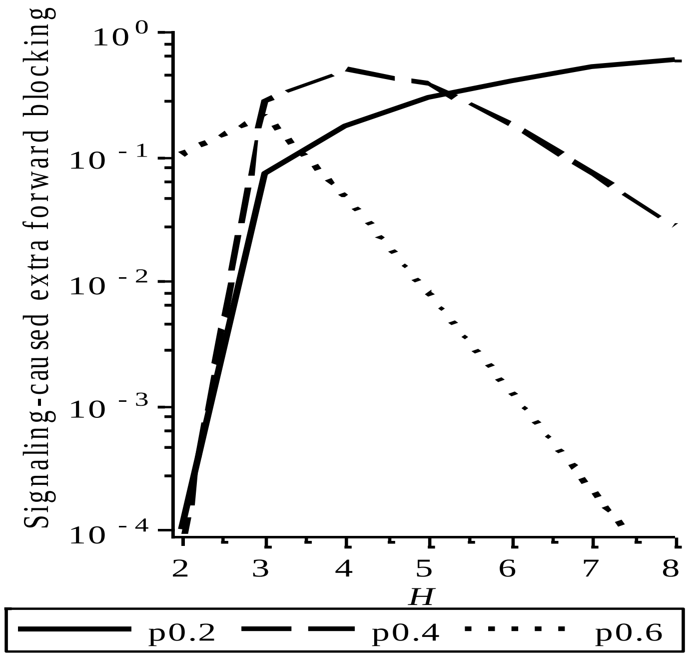
(a) Same-wavelength-use



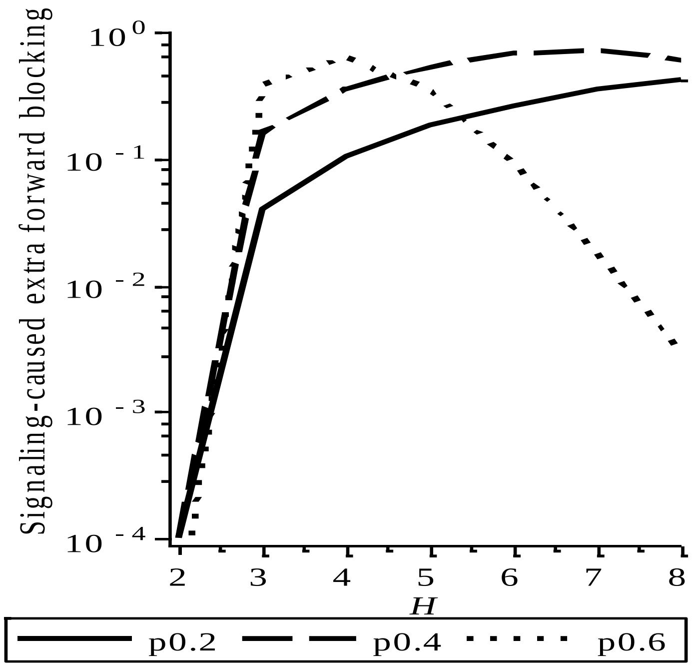
(b) Different-wavelength-use

(F=1, W=64, H=4, b=0.001)

The Signaling Caused Extra Forward Blocking vs. the Number of Hops in UL (after the 2nd signaling)



(a) Same-wavelength-use

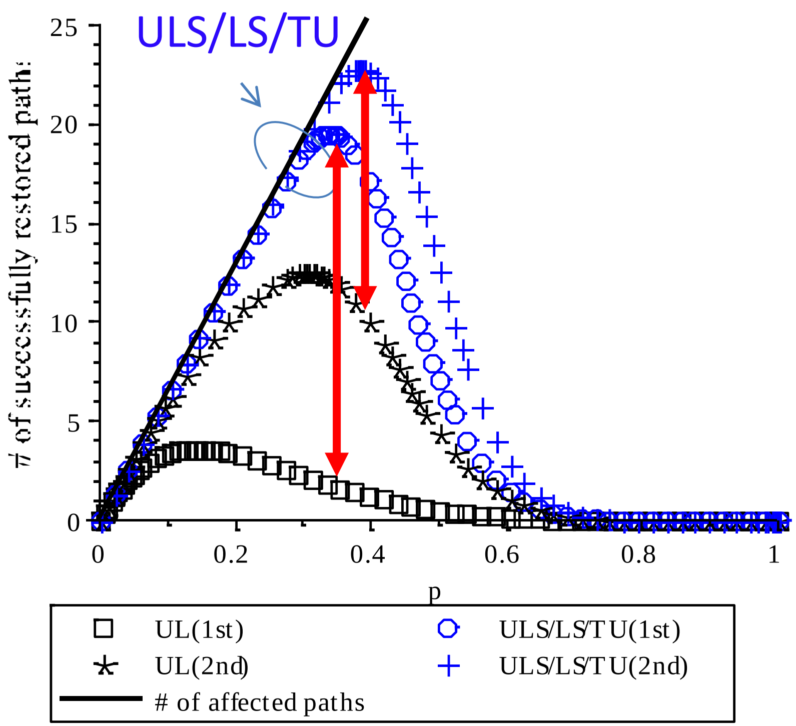


(b) Different-wavelength-use

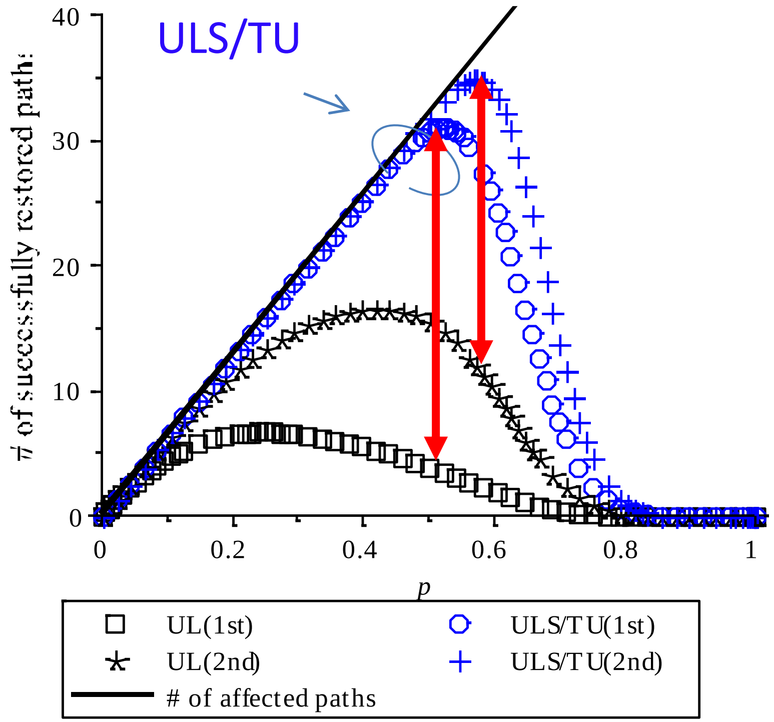
(F=1, W=64, b=0, p=0.2, 0.4 and 0.6)

Blocking Probability in the Restoration Scenarios

- ULS/LS/TU can successfully recover most of paths, outperforming UL significantly.
- In particular, if recover time needs to be kept short, and reduce the burst control overhead, only 1st time signaling might be preferred.



(a) Same-wavelength-use



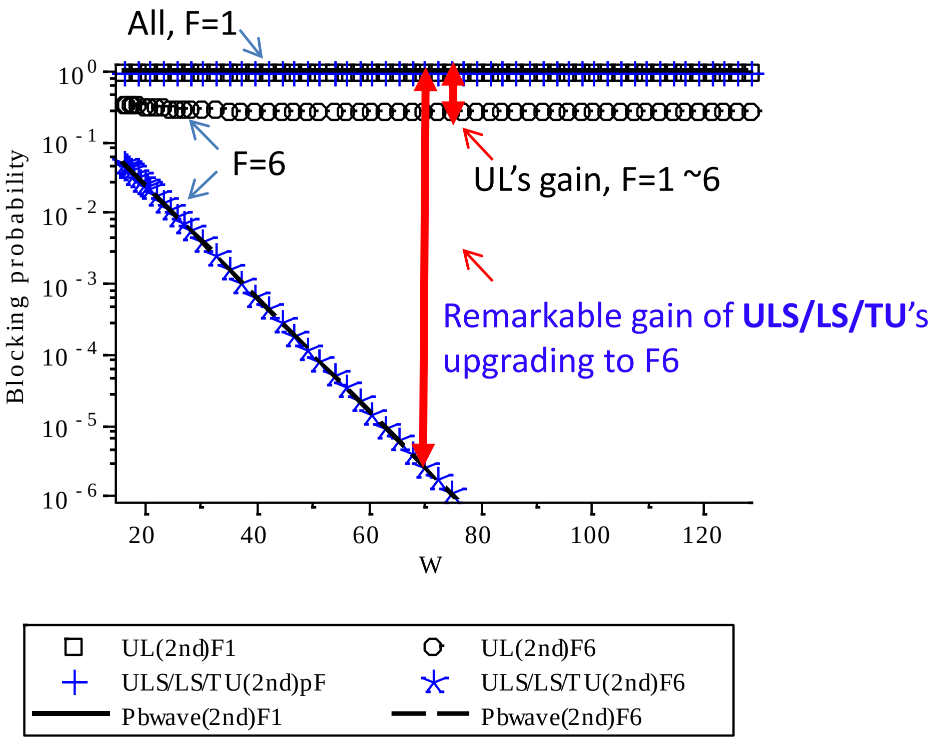
(b) Different-wavelength-use

(F=1, W=64, H=4, b=0.001)

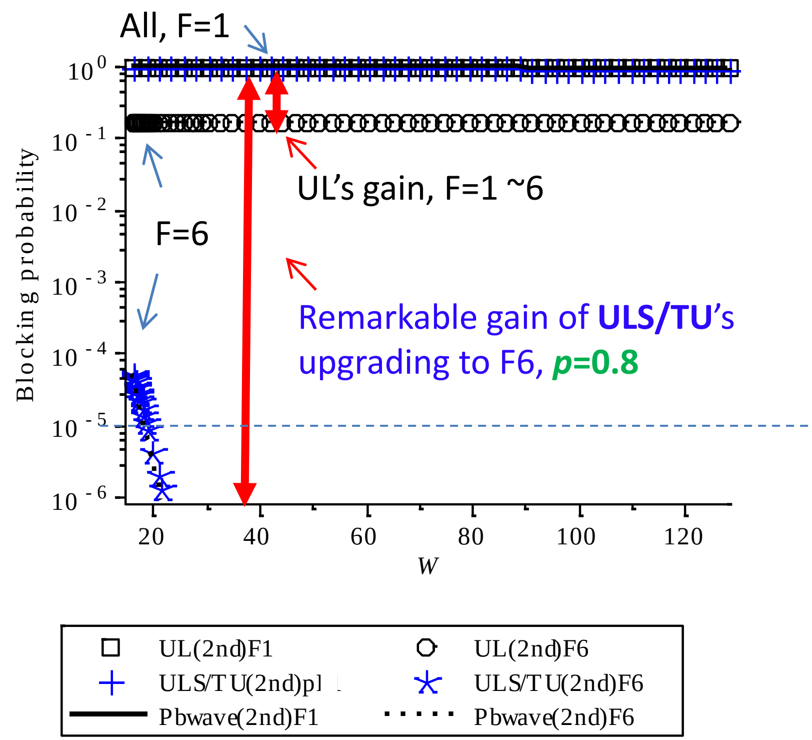
Blocking Probability in the Upgrade Scenarios

-UL cannot effectively take advantage of expended resource (fiber/wavelength)

-Even ***p*=0.8**, multifiber WSON has the perfect performance (if ULS/LS/TU is employed)



(a) Same-wavelength-use



(b) Different-wavelength-use

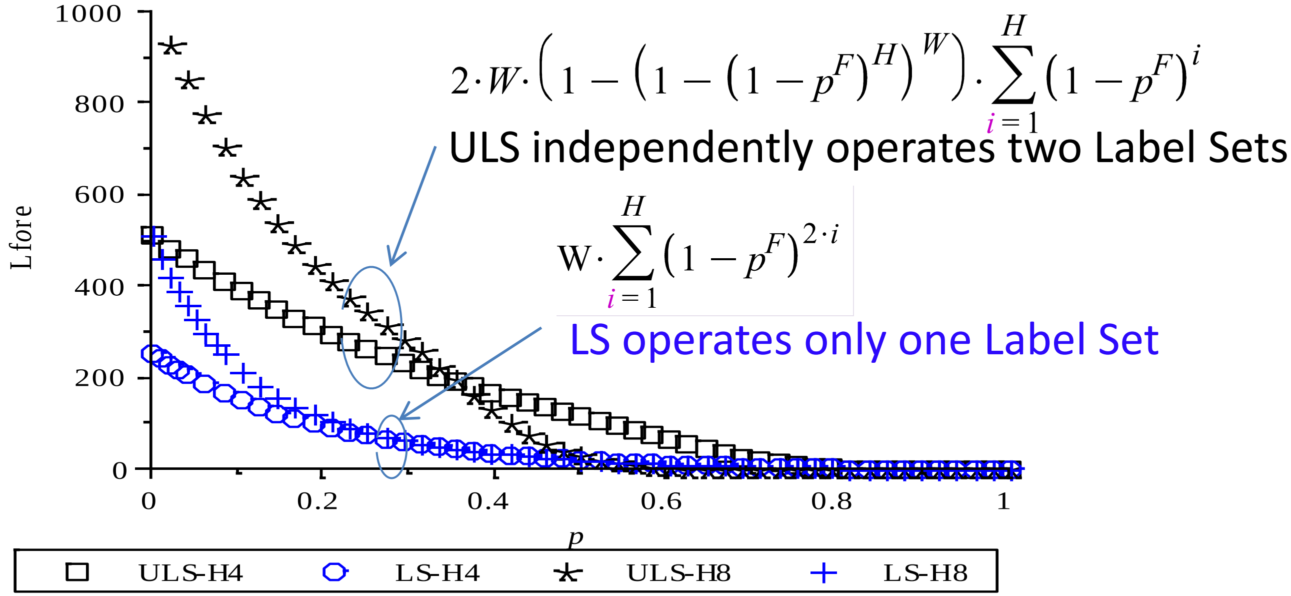
(H=4, p=0.8, b=0.001, F=1 and 6)

Protocol Cost Issue-1: Total Number of Traversed Hops in One Set of Signaling

	ULS	LS	TU
Same-wave-use	3H	3H	11H
Different-wave-use	3H	N/A	9H

Cost of TU is implementation dependent

Protocol Cost Issue-2: Accumulated Label-processing "Times" for ULS and LS (Same Wavelength Use)



Lfore stands for the labels amount in singling of forwarding direction

(F=1, W=64, b=0.001, H=4 and H=8)

Major Findings Summary

- Focused on the signaling- based wavelength assignment needs and performance analysis for co-routed bi-directional lightpath provisioning

- Single RWA solution specification approach in simple current signaling (RSVP-TE per RFC3471, RFC3473 highly relies on the up-to-date info dissemination (resulting in a heavy load of routing on control plane)
  - Needs robust distributed WA support with signaling even in centralized RWA architectures (relaxing the strict dependency on the up-to-date info and frequent routing)

- **Review the questions again. How about the capability of Signaling schemes on Distributed WA?:**

Q: Is the current standard RSVP-TE enough?

Finding: Upstream Label (UL) approach is of poor performance in terms of distributed WA capability

Q: Are there any possibilities for service providers to provide more cost efficient lightpath service?

Finding: Three signaling-based WA approaches are available

- Two-Uni has the highest flexibility but the performance depends on implementation
- ULS extends the idea of Label Set in upstream direction
- LS reuses the Label Set (optimizes signaling in the same-wavelength-use scenario)

Q: How about the possible gain by employing the extension?

Finding: The candidate approaches outperform the UL significantly (blocking performance)

- Especially, in restoration scenario and a long-term view (in case of future WSON upgrading)

Thank you !