Networks 2008, Sep. 28-Oct. 2

University of Ottawa
Canada's university

School of Information Technology & Engineering

Mazen Khair,
Presents:

Distributed Fault Localization for Multi-Domain All-Optical Networks without Power Monitoring

uOttawa
L'Université canadienne
Canada's university

Authors: Mazen G. Khair,
Jun Zheng, and
Hussein. T. Mouftah

Presentation Outline

- Intra-domain fault localization background
- Inter-domain fault localization background
- Limited-perimeter Vector Matching Protocol (LVM)
- Objective
- Inter-domain Localization Protocol without Power Monitors
  - *Case A: Inter-domain failure caused by intra-domain link failure*
  - *Case B: Inter-domain failure caused by inter-domain link failure*
  - *Case C: Intra-domain failure caused by intra-domain link failure*
- Delay analysis for the three cases
- Results

uOttawa

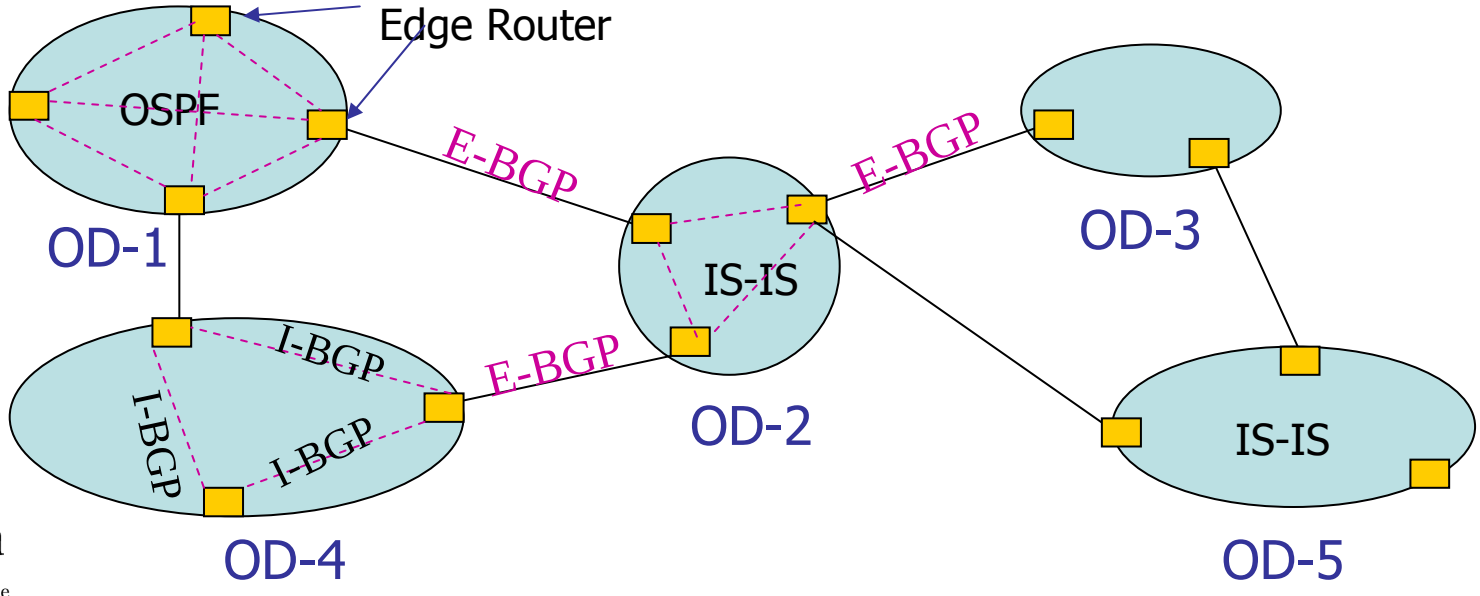
L'Université canadienne
Canada's university

Background <Intra-domain>

- Open Shortest Path First (OSPF):
  - By default each router sends "***Hello packets"*** on each interface every 10sec.
  - If no "***Hello packets"*** reply back from its neighbor within 40 sec, the link to that neighbor is considered down "Failed Link is localized".
- Failure localization based on having power monitor devices at each node that generates alarms upon failure detection.
  - Redundant and large number of alarms
  - Increases node Cost
  - Requires proper placement

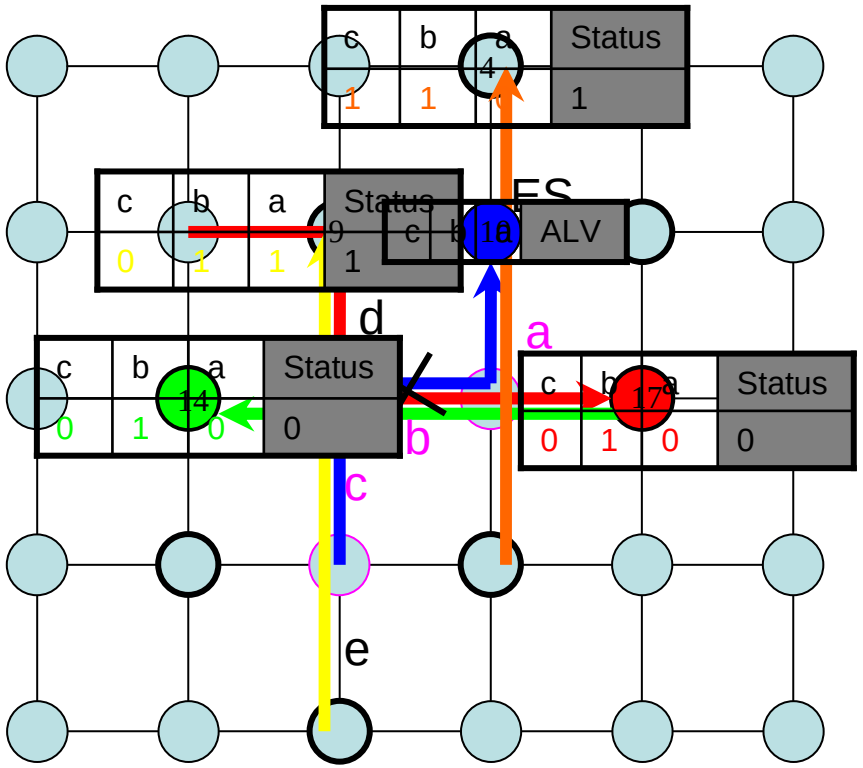
Background <Inter-domain localization – BGP, OBGP, ORBGP>

- **E-BGP:**
  - Used between two edge routers that belong to different ODs.
  - There is always a physical link between the two participants.
  - Routes are picky based on configured policy. Result routing oscillation.
- **I-BGP:**
  - This mode is used to exchange routing information among routers that belong to the same OD.
  - There are no physical link among the participants “logical connection/Full mesh”. Routing miss-configuration is very likely to happen.



Limited-perimeter Vector Matching Protocol (LVM)

c	b	a	Status	
0	1	1	1	Node 9
c	b	a	Status	
1	1	0	1	Node 4
c	b	a	Status	
0	1	0	0	Node 17
c	b	a	Status	
0	1	0	0	Node 14
c	b	a	Result of **AND** operation	
0	**1**	**0**		



Link C is up

Link A is up

Result: Link B is down

uOttawa

L'Université canadienne
Canada's university

LVM: Limited-perimeter Vector Matching fault localization Protocol

ALV: Affected Link Vector

Objective

- Localize an inter-domain failure due to:
  - Inter-domain link failure
  - Intra-domain link within Optical Domain (OD) that cause inter-domain effect
- Avoid exchanging any vital information about network topology among different ODs
- Interaction between intra-domain and inter-domain localization protocol
- Contain the inter-domain failure effect

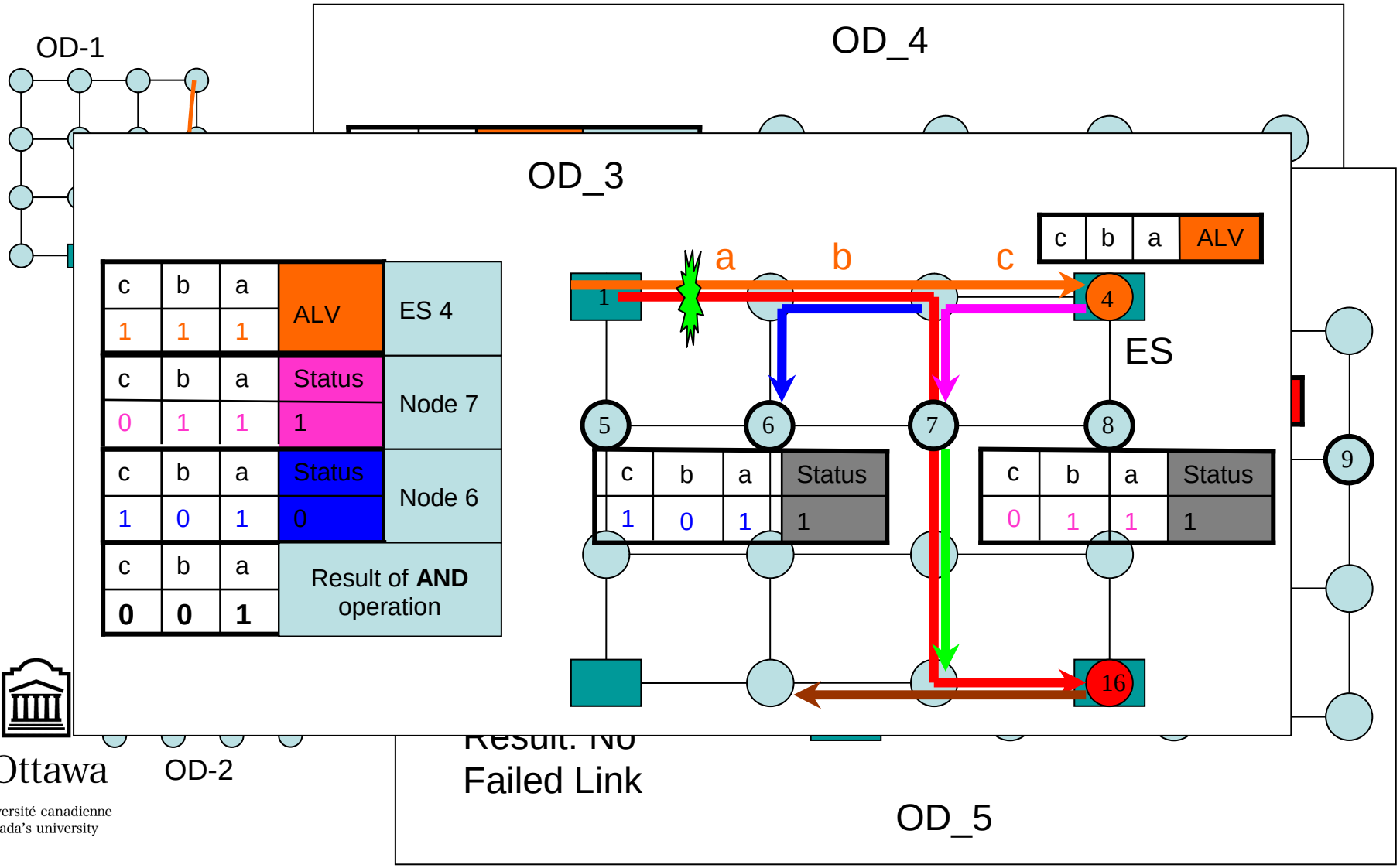
Inter-domain Localization

- The fault localization protocol can be divided into two mode of operation:
  - Intra-domain localization: This mode of operation is intended to localize a link failure within a faulty domain. “Simple, Use LVM”
  - Inter-domain localization: This mode of operation is intended to localize a ***faulty domain*** or an ***inter-domain link failure***.

uOttawa

L’Université canadienne
Canada’s university

Case A: Localizing a Faulty Domain



Case A: Time Analysis for Localizing a Faulty Domain

- Delay Analysis <Max case>
  - (1) Detection phase, $T_1 = H(\gamma \times D_{OD}) + (H-1)(\gamma_{inter\_link})$
  - (2) Broadcasting phase, $T_2 = \gamma \times D_{OD}$
  - (3) Multicasting phase, $T_3 = \gamma \times D_{OD}$
  - (4) Matching phase, $T_4 = \theta \times D_{OD}^2$
  - (5) Responding phase, $T_5 = \gamma \times D_{OD}$
  - (6) Concluding phase, $T_6 = \theta$
  - Plus Extra time, $T_{Max\_Extra} = \gamma \times D_{OD}$

H : Number of Optical Domains that a failed lightpath cross

D_{OD}: Longest diameter among all the domains

γ : Propagation delay value along the intra-domain link

θ : Denote the computational cycle

Case A: Time Analysis for Localizing a Faulty Domain *"Continue"*

❑ *Time Analysis, Maximum delay*

$$T_{Inter\_Intra}^{\max} = T_{\max\_extra} + \sum_{i=1}^{6} T_i = \gamma \times D_{OD}(H+4) + (H-1)(\gamma_{inter\_link}) + \theta \times D_{OD}^2 + \theta$$

For a grid network with *MxN* nodes, $D_{OD} = M + N - 2$ If we assume *M=N*, $D_{OD} = 2N - 2$

$$T_{Inter\_Intra}^{\max} = 2\gamma(N-1)(H+4) + (H-1)(\gamma_{inter\_link}) + \theta\left((2(N-1))^2 + 1\right)$$

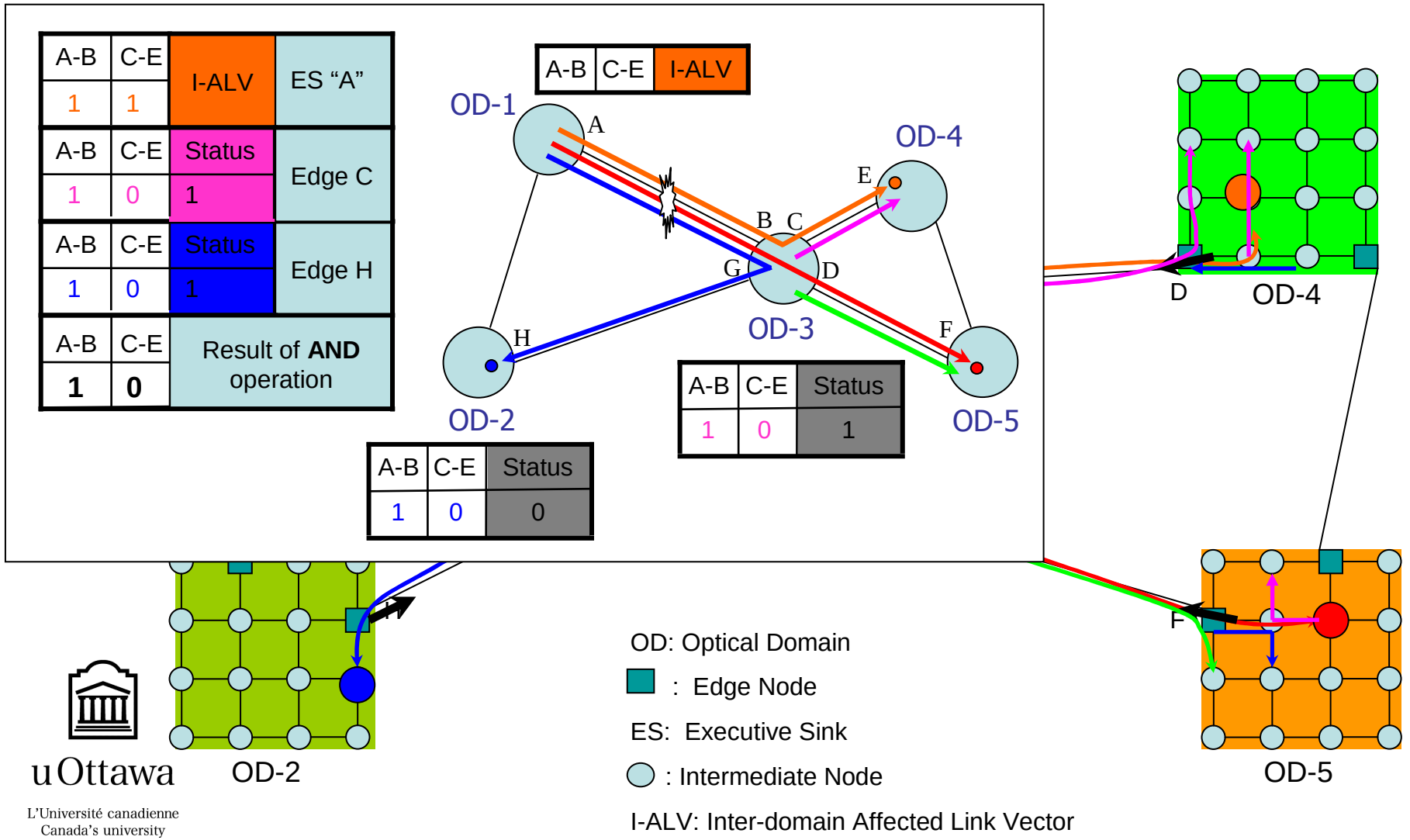
If we assume that the affected lightpath passes through H optical domains and (H-1) inter-domain link. The total delay can be expressed as:

$$T_{Inter\_Intra}^{total\_\max} = T_{Inter\_Intra}^{\max} + (H-1)\sum_{i=3}^{6} T_i + (H-1)(\gamma_{inter\_link})$$

$$= T_{Inter\_Intra}^{Max} + (H-1)(2\gamma D_{OD} + \theta \times D_{OD}^2 + \theta) + (H-1)(\gamma_{inter\_link})$$

$$= 2\gamma(N-1)(3H+2) + H\theta\left((2(N-1))^2 + 1\right) + 2(H-1)(\gamma_{inter\_link})$$

Case B: Localizing an Inter-Domain Failed Link



uOttawa

L'Université canadienne
Canada's university

Case B: Time Analysis for Localizing an Inter-Domain Failed Link

Case B localization time is the sum of Case A delay plus delay of the last 4 phases!

$$T_{Inter\_Inter}^{Total\_Max} = T_{Case\ A}^{Total\_Max} + \sum_{i=3}^{6} IntT_i$$

$$T_{Inter\_Inter}^{Total\_\max} = T_{Case\ A}^{Total\_\max} + 2\left(\gamma\left((H-2)\times D_{OD}\right) + \left((H-1)\gamma_{inter\_link} + \gamma_{inter\_link}\right)\right) + \theta\left((H)^2\right) + \theta$$

$$= T_{Case\ A}^{Total\_\max} + 2\left(\gamma\left((H-2)\times D_{OD}\right) + \left(H\gamma_{inter\_link}\right)\right) + \theta\left((H)^2\right) + \theta$$

For a grid network with *MxN* nodes, $D_{OD} = M + N - 2$ If we assume $M=N$, $D_{OD} = 2N - 2$

$$T_{Inter\_Inter}^{Total\_\max} = T_{Case\ A}^{Total\_\max} + 2\gamma\left((H-2)\times(2N-2)\right) + 2\left(H\times\gamma_{inter\_link}\right) + \theta\left((H)^2\right) + \theta$$

uOttawa

L'Université canadienne
Canada's university

Case C: Time Analysis for Localizing an Intra-Domain Failed Link

- The total maximum delay can be calculated as

$$T^{\max}_{Intra\_Intra} = \left(T_{\max\_extra}\right) + \sum_{i=1}^{7} T_i = \left(\gamma \times D_{OD}\right) + 4 \times \gamma \times D_{OD} + \theta \times D_{OD}^2 + \theta$$

- In terms of *N* and *M and* If we assume *M=N*

$$T^{\max}_{Intra\_Intra} = \left(5 \times \gamma \times \left(N + M - 2\right)\right) + \theta \times \left(N + M - 2\right)^2 + \theta$$

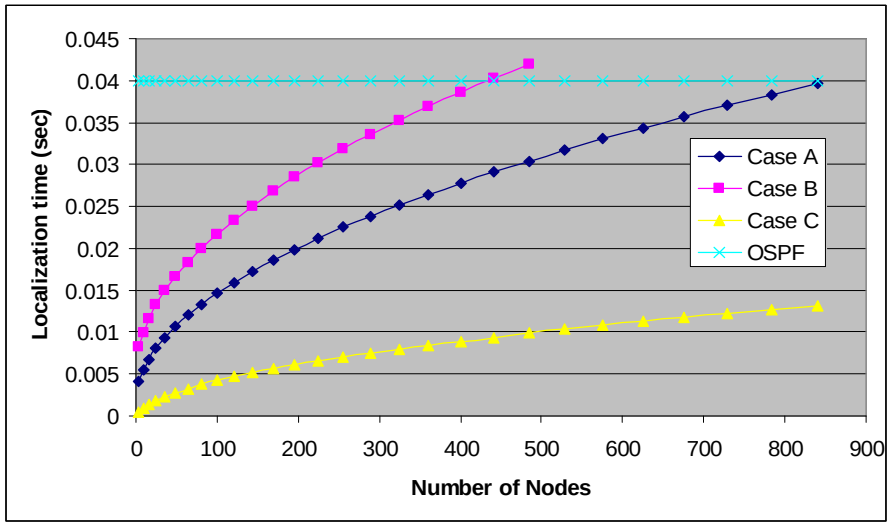
$$T^{\max}_{Intra\_Intra} = \gamma 10\left(N - 1\right) + \theta\left(4N^2 - 8N + 5\right)$$

Used Parameters

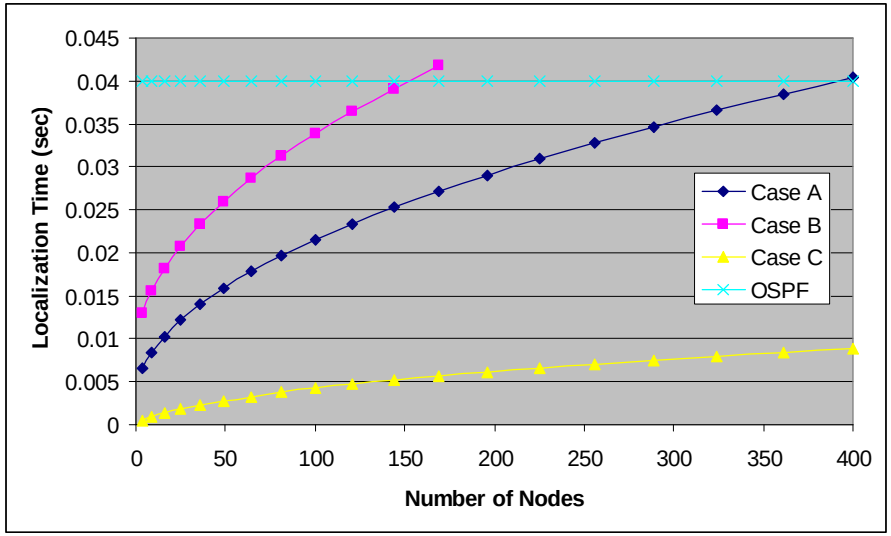
- Intra-domain link: 10k meter
- Inter-domain link: 100k meter
- Propagation delay (γ) : 2.14 x 10^8m/s
- Computational cycle (θ): 20ns
- Different grid networks MxN Or NxN size
- Different number of Optical Domains (H)

Results !

- *Number of Optical Domains is 4*
- *Number of nodes per domain is variable*



- *Number of Optical Domains is 6*
- *Number of nodes per domain is variable*

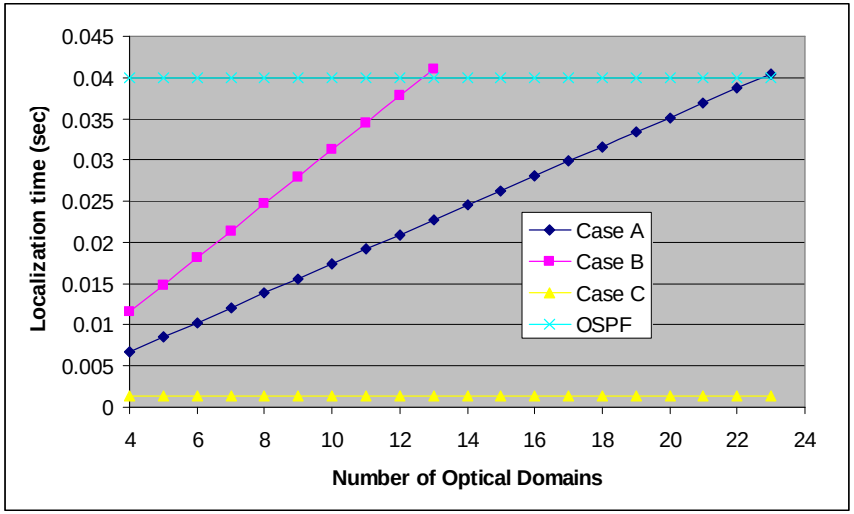


uOttawa

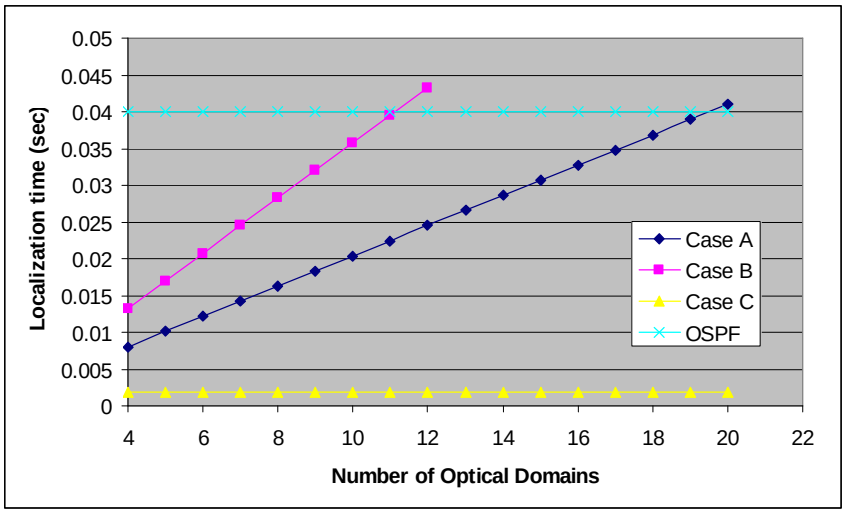
L'Université canadienne
Canada's university

Results !

- *Number of Optical Domains is variable*
- *Number of nodes per domain is 16*



- *Number of Optical Domains is variable*
- *Number of nodes per domain is 25*



Thank you!

- Questions?

- Mazen Khair
  - Email: mkhair@site.uottawa.ca
- Dr. Jun Zheng
  - Email: vjzheng@site.uottawa.ca
- Prof. Hussein Mouftah
  - Email: mouftah@site.uottawa.ca

uOttawa

L'Université canadienne
Canada's university