Optical XCP for Small Buffered Optical Packet Switching Networks

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Outline

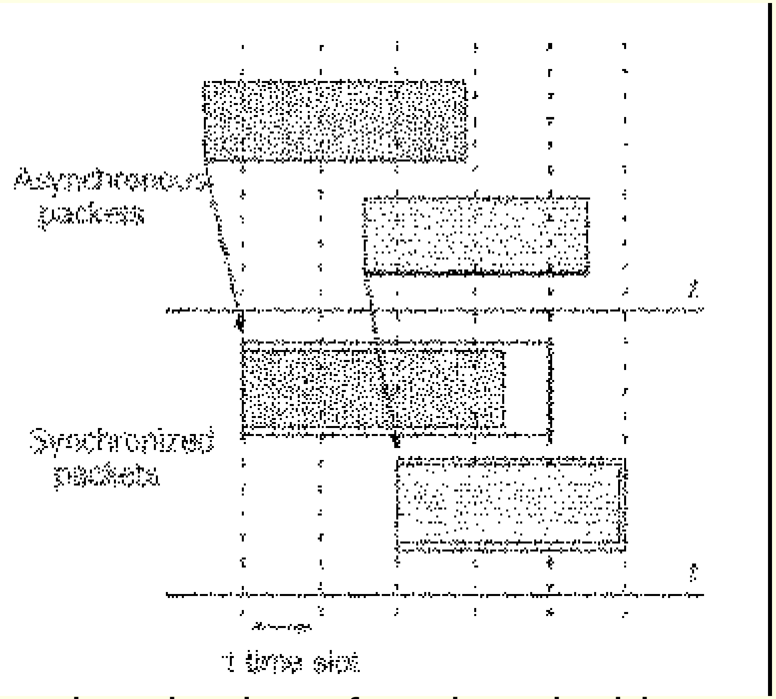
- **Problems in OPS networks**
- **Architecture**
- **Objective**
- **Proposed Solutions**
- **Simulation Results**
- **Conclusions**

Problems in OPS Networks

- **Optical RAM is not available**
  - Electronic RAM is not a feasible solution
  - O/E/O conversion is hard at ultra-high speed of optical networks
  - Possible to use FDLs (fiber-delay-lines) for buffering
  - FDLs can provide small amount of buffering with fixed delays
- **Switching and Processing**
  - Hard to use complex algorithms
  - All-optical switching is necessary

Architecture

- **OPS Architecture**
  - Time-slotted WDM OPS network
  - Variable length IP packets enter OPS domain without aggregation

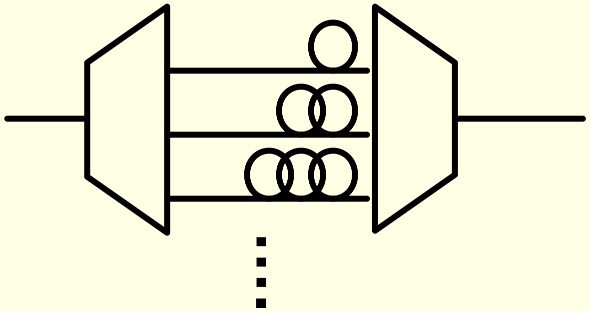


Synchronization of packets inside a router

Architecture

FDL Architecture

- Single stage FDL set with B delay lines
- FDL length distribution increases linearly (x,2x,3x,4x….) where x is FDL granularity
  - » FDL granularity of 3 means a FDL set of (3 slots, 6 slots, 9 slots, 12 slots….)
- Voids occur between packets inside FDLs when x>1
- No void-filling
- Output buffering



Objective

- **Designing an all-optical OPS architecture that can achieve high utilization and low packet drop ratio by using small buffers**
- **Showing the buffer requirements**

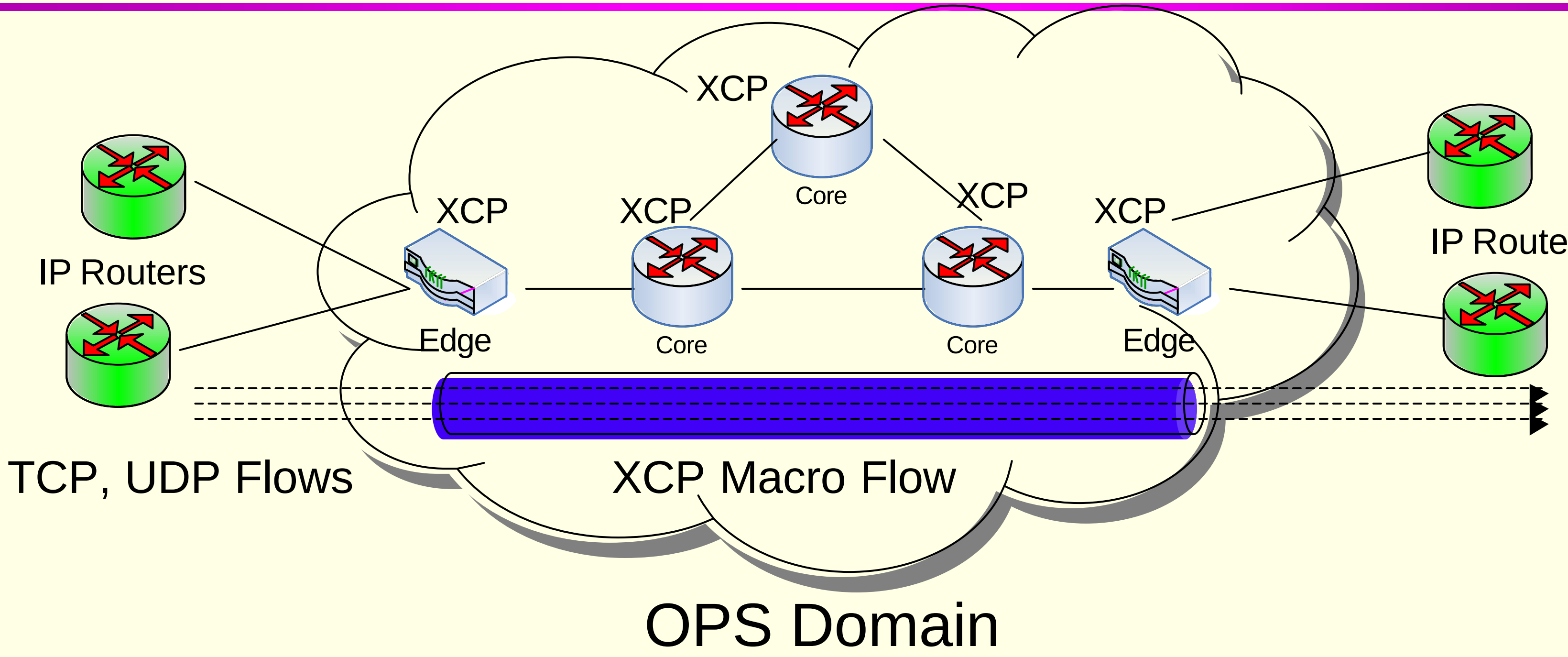
Advantages

- **Decreasing the buffer requirements in the core**
- **Realizing all-optical high-speed OPS networks**

Proposed Solutions 1/2

- **Preventing wavelength over-utilization**
  - Apply XCP-based congestion control
  - Carefully select XCP parameters
  - Control maximum wavelength utilization ratio
- **XCP feedbacks**
  - Carry feedbacks in probe packets
  - Possible to use a control wavelength for feedbacks
  - Control wavelength can be slow enough for O/E/O conversion, updating headers and calculating feedbacks

Proposed Solutions 2/2



- **Burstiness**
  - Establish macro flows between edge nodes
  - Assign incoming TCP, UDP flows to macro flows (similar to XCP-CSFQ, TeXCP)
  - Apply token-based leaky bucket pacing to macro flows according to XCP flow rate at edge node
  - Possible to use LSPs for controlling macro flows if GMPLS is available

Selecting Target Utilization 1/2

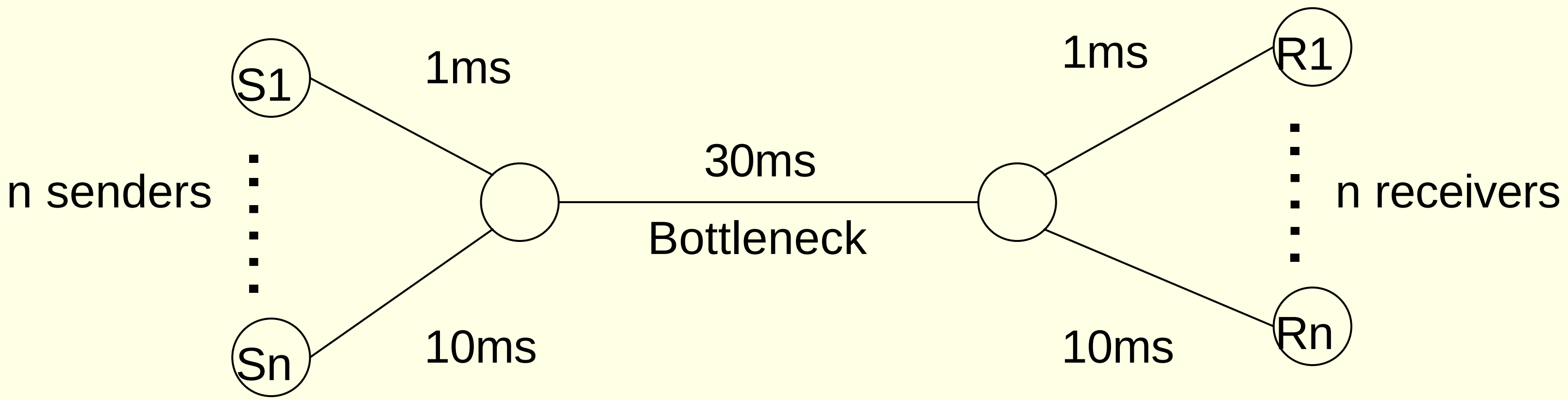
- **At each XCP core node, wavelength capacity must be explicitly given to XCP control algorithm**
- **By giving a false capacity value to XCP lower than actual wavelength capacity:**
  - XCP algorithm converges to the given false capacity
  - Possible to control maximum wavelength utilization
  - Can be explicitly given as a target utilization

Selecting Target Utilization 2/2

- **Careful selection of target utilization can prevent**
  - Effective load overshoots of core routers due to voids in FDLs
  - Utilization overshoots due to congestion and oscillations caused by XCP algorithm
  - Core buffer buildups

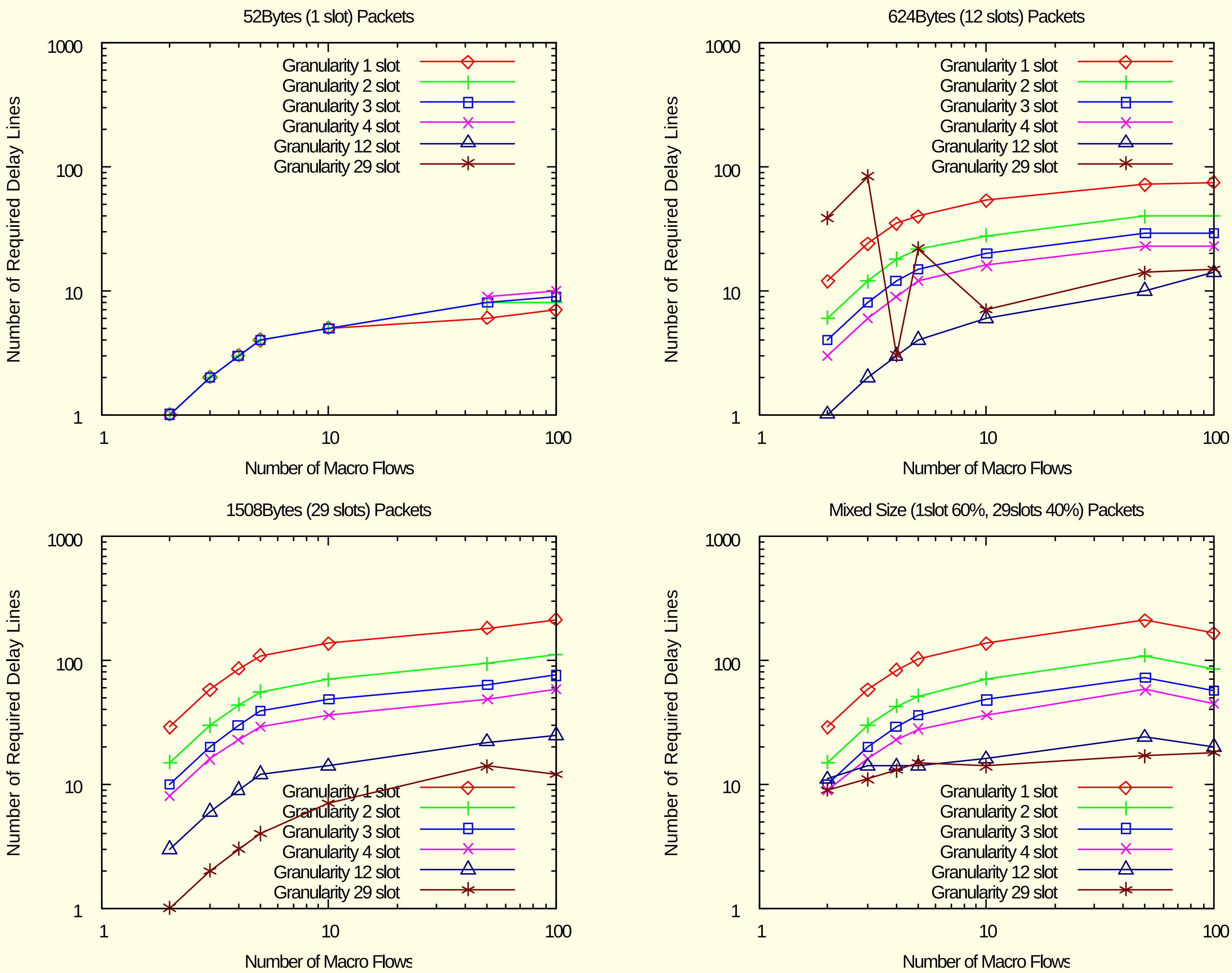
Simulation Settings

- **Slotted OPS with single data wavelength**



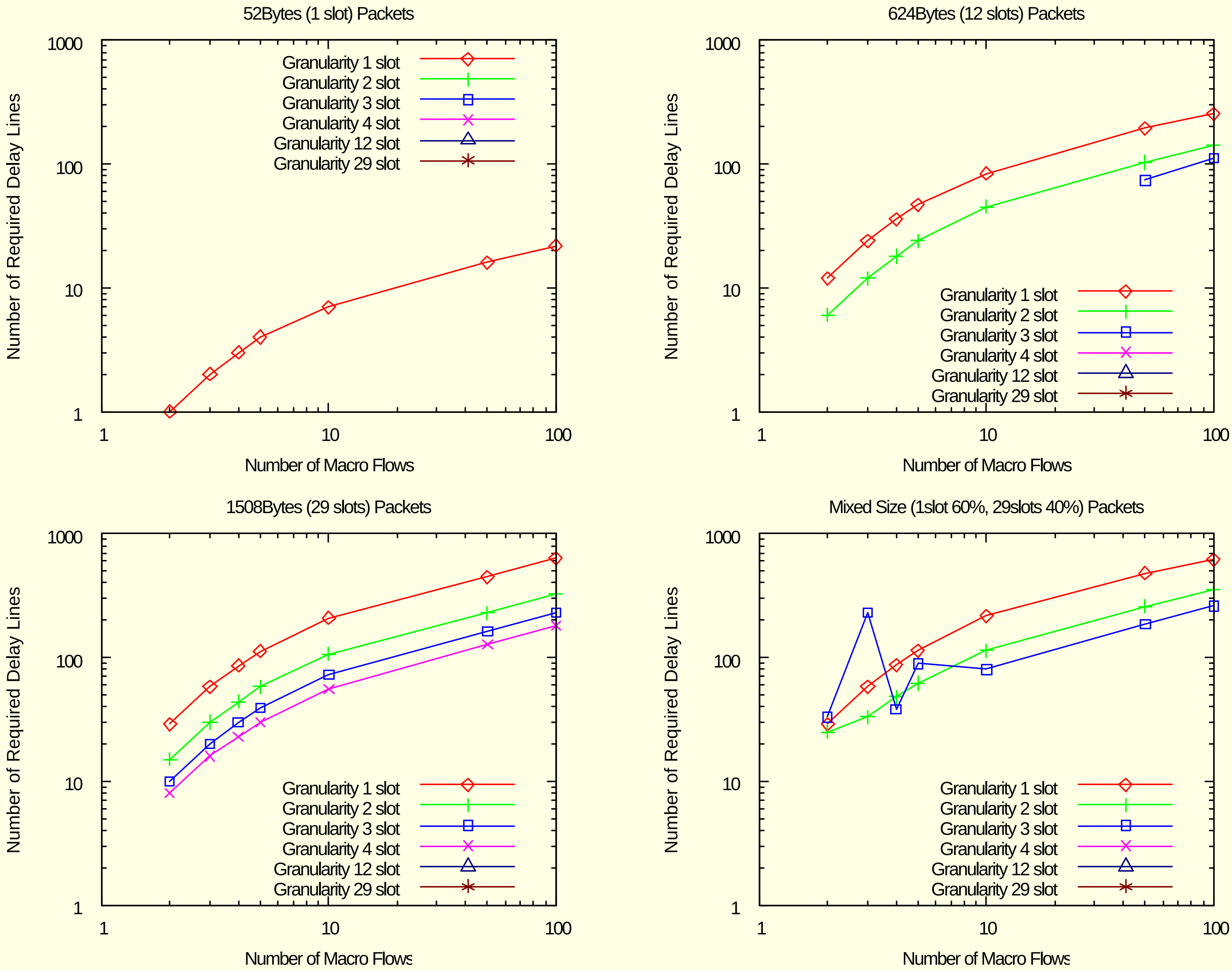
- **Wavelength speed ranging from 172Mbit/s to 5Gbit/s**
- **Simulation duration is 40seconds**
- **Slot size is 52 Bytes**
- **Edge XCP agents always have packet to send**
- **Packet size distribution**
  - All packets are 1 slot size (52 Bytes)
  - All packets are 29 slot size (1508 Bytes)
  - All packets are 12 slot size (624 Bytes)
  - Mixed Size (60% of packets are 1 slot size, 40% of packets are 29 slot size)

FDL Requirements
(Target Utilization 30%)



52Bytes (1 slot) Packets
Number of Required Delay Lines
Number of Macro Flows
1000
100
10
1
1
10
100
Granularity 1 slot
Granularity 2 slot
Granularity 3 slot
Granularity 4 slot
Granularity 12 slot
Granularity 29 slot
624Bytes (12 slots) Packets
Number of Required Delay Lines
Number of Macro Flows
1000
100
10
1
1
10
100
Granularity 1 slot
Granularity 2 slot
Granularity 3 slot
Granularity 4 slot
Granularity 12 slot
Granularity 29 slot
1508Bytes (29 slots) Packets
Number of Required Delay Lines
Number of Macro Flows
1000
100
10
1
1
10
100
Granularity 1 slot
Granularity 2 slot
Granularity 3 slot
Granularity 4 slot
Granularity 12 slot
Granularity 29 slot
Mixed Size (1slot 60%, 29slots 40%) Packets
Number of Required Delay Lines
Number of Macro Flows
1000
100
10
1
1
10
100
Granularity 1 slot
Granularity 2 slot
Granularity 3 slot
Granularity 4 slot
Granularity 12 slot
Granularity 29 slot

FDL Requirements
(Target Utilization 90%)

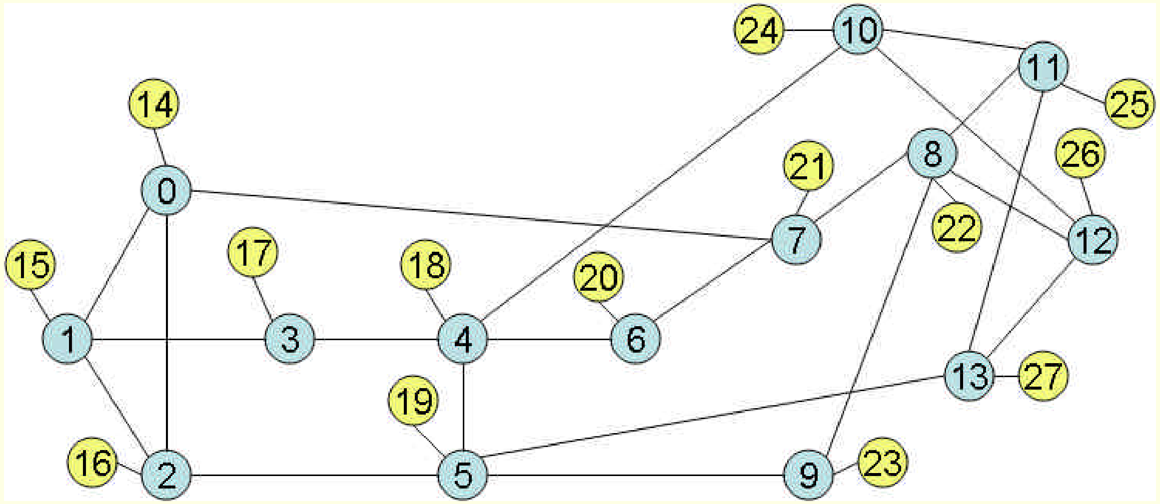


52Bytes (1 slot) Packets
624Bytes (12 slots) Packets
1508Bytes (29 slots) Packets
Mixed Size (1slot 60%, 29slots 40%) Packets
Number of Required Delay Lines
Number of Macro Flows
1000
100
10
1
Granularity 1 slot
Granularity 2 slot
Granularity 3 slot
Granularity 4 slot
Granularity 12 slot
Granularity 29 slot

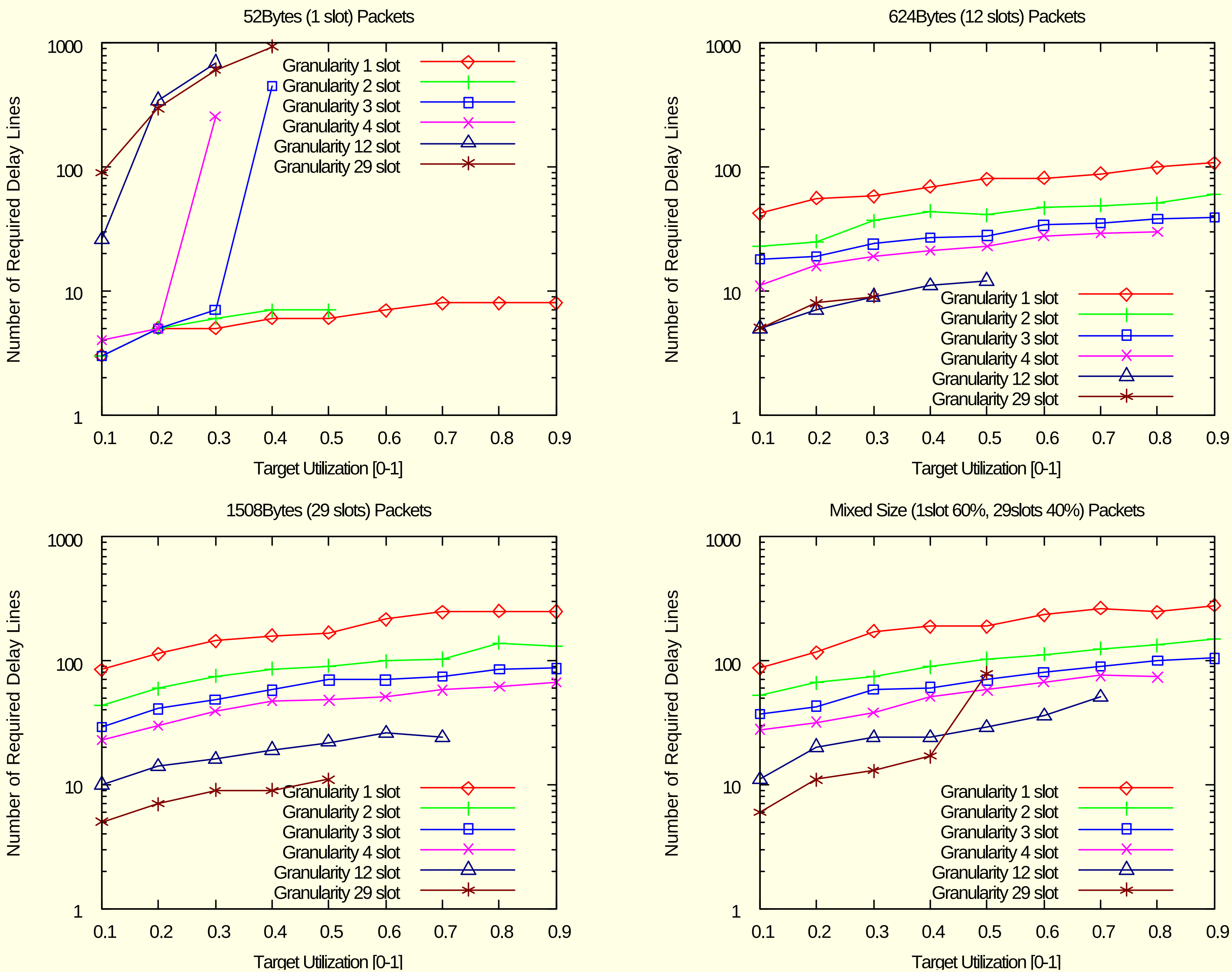
Conclusions and Future Work

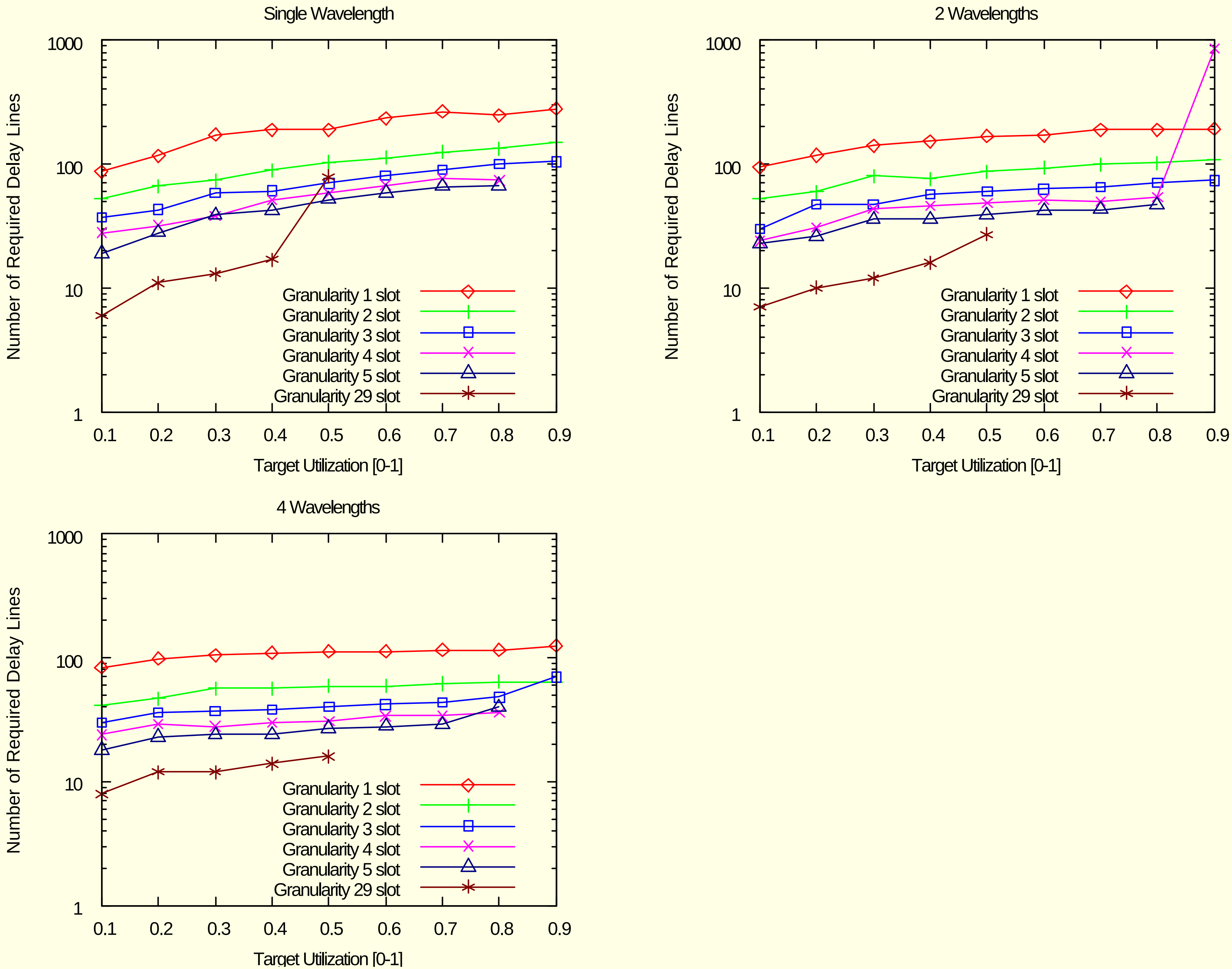
- **Conclusions**
  - Possible to control FDL requirements by applying pacing at edge, controlling the number of LSPs on a wavelength and limiting wavelength utilization
  - XCP allows limiting utilization of wavelengths at a stable level in order to prevent queue-buildups
  - Voids in FDLs can make the system unstable and cause drastic packet loss ratios
  - Necessary to consider possible packet size distributions in order to minimize buffer requirements and guarantee stable operation
- **Future Work**
  - Multistage FDLs can further decrease the FDL requirements.
  - Optimum size of electronic buffers on edge nodes

NSFNET Simulation Settings



- 28 nodes (14 edge + 14 core) and 35 links (21 core + 14 edge)
- Core nodes use only FDL for buffering
- Each edge source node sends traffic to all other edge nodes
- Edge XCP agents always have packet to send to other edge nodes
- Simulation duration is 40 seconds
- Edge XCP agents start randomly in the first 10seconds
- Wavelength speed ranging from 70Mbit/s to 2Gbit/s depending on simulated packet size distribution


52Bytes (1 slot) Packets
624Bytes (12 slots) Packets
1508Bytes (29 slots) Packets
Mixed Size (1slot 60%, 29slots 40%) Packets
Number of Required Delay Lines
Target Utilization [0-1]
1000
100
10
1
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Granularity 1 slot
Granularity 2 slot
Granularity 3 slot
Granularity 4 slot
Granularity 12 slot
Granularity 29 slot


Single Wavelength
2 Wavelengths
4 Wavelengths
Number of Required Delay Lines
Target Utilization [0-1]
1000
100
10
1
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Granularity 1 slot
Granularity 2 slot
Granularity 3 slot
Granularity 4 slot
Granularity 5 slot
Granularity 29 slot