Optical Burst Switching

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Outline

UTD

- Overview of Today's Optical Network
- Future Optical Network Requirements
- Introduction to Optical Burst-Switched Networks
- Research Contributions and Ongoing Works
  - Reactive Contention resolution
  - Proactive Contention resolution
- Concluding Remarks

Thinking Telephony ?

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"Well-informed people know it's IMPOSSIBLE to transmit voice over wires and that were it possible to do so, the thing would be of NO practical value."

Boston Post, 1865, quote from an article concerning the arrest of a man who had been attempting to raise funds for work on a telephone

Today's Network

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Small Phones

Desktops

Laptops

Web enable PDAs

GPS Receivers

Mainframes

Routers

Today's Network Facts .....

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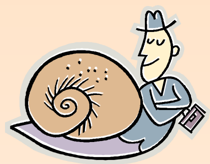
- In 2005 over one billion people will be using Internet services
- 1.3 billion people send over 244 billion messages every month
- The total number of cell phones in the world is estimated to be one billion as of 2004
- More than 20 million PDAs have been sold

"Internet traffic is (almost) doubling every year."

Future Network
Still Going ...

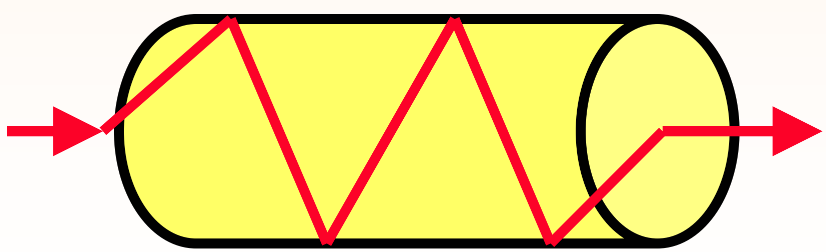


“This is not your father’s network.”

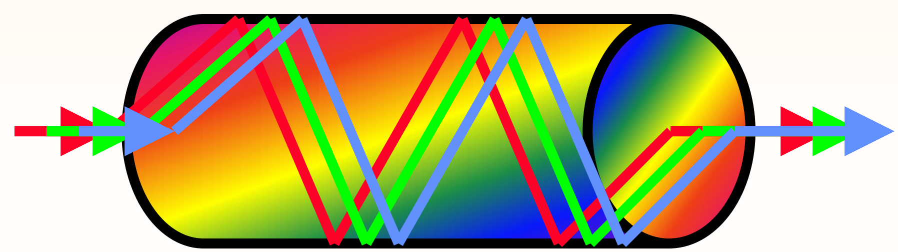
- Satisfying on-demand high-bandwidth requests is critical
- Emerging Applications (*Killer apps*)
  - Digital theater
  - High quality collaborative work (video conferencing)
  - Connecting Xboxes
  - Medical image processing and remote visual steering

Fiber Rules !

- Optical technology is essential in future networks
  - High bandwidth
  - Less susceptible to interferences
  - Low degradation over long distances
- Optical wavelength division multiplexing (WDM) plays a key role
  - Allowing transmitting multiple wavelengths on a single fiber link
  - Increasing transmission capacity



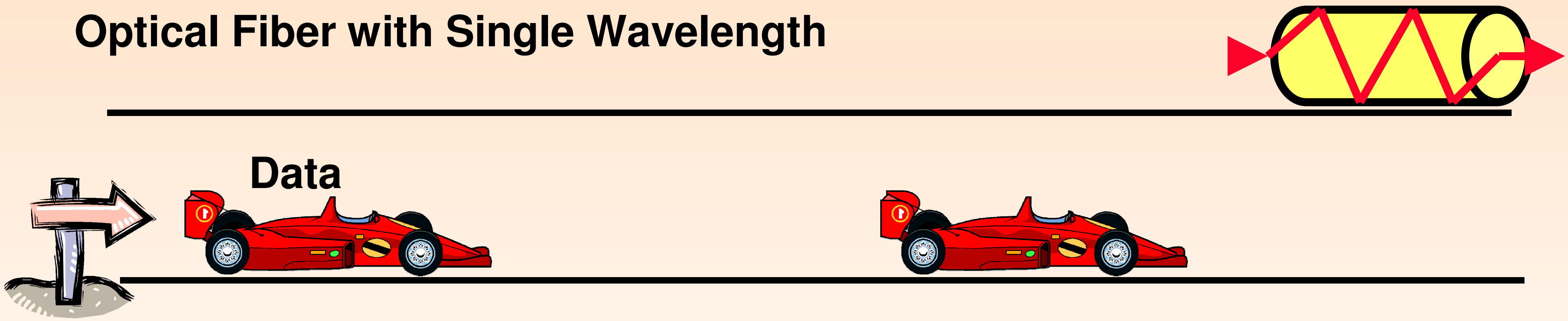
Single Wavelength



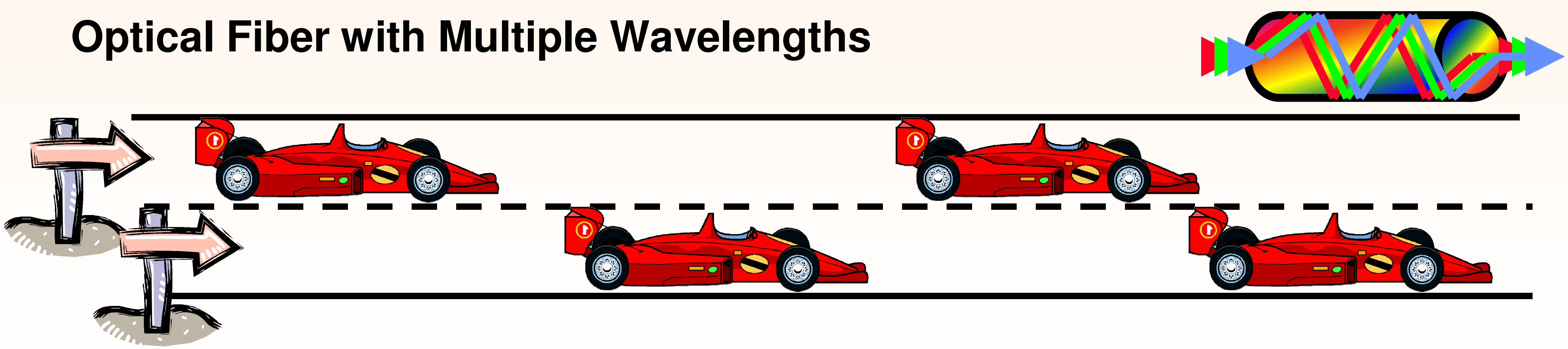
Multiple Wavelengths

High-Speed Highway

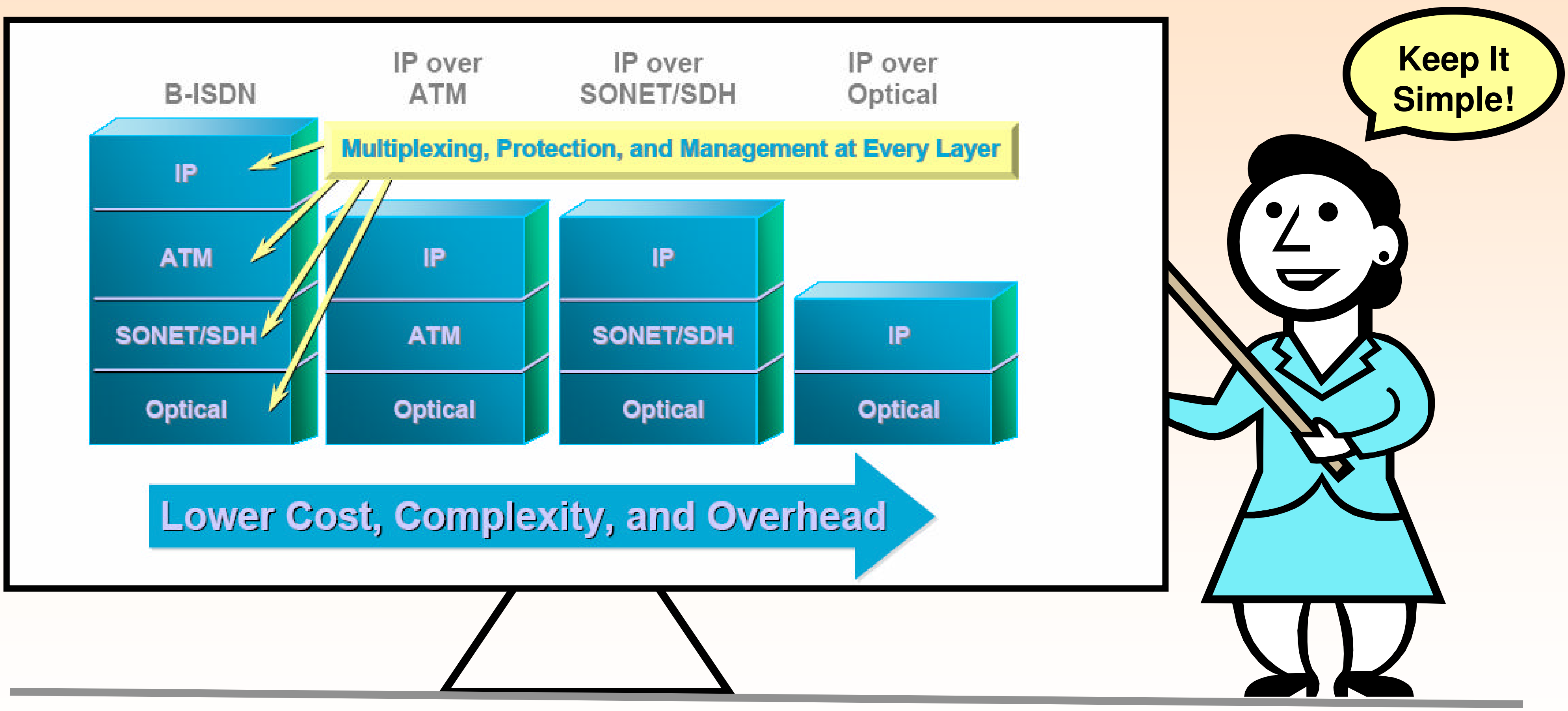
Optical Fiber with Single Wavelength



Optical Fiber with Multiple Wavelengths



Future Network
Next Generation Characteristics

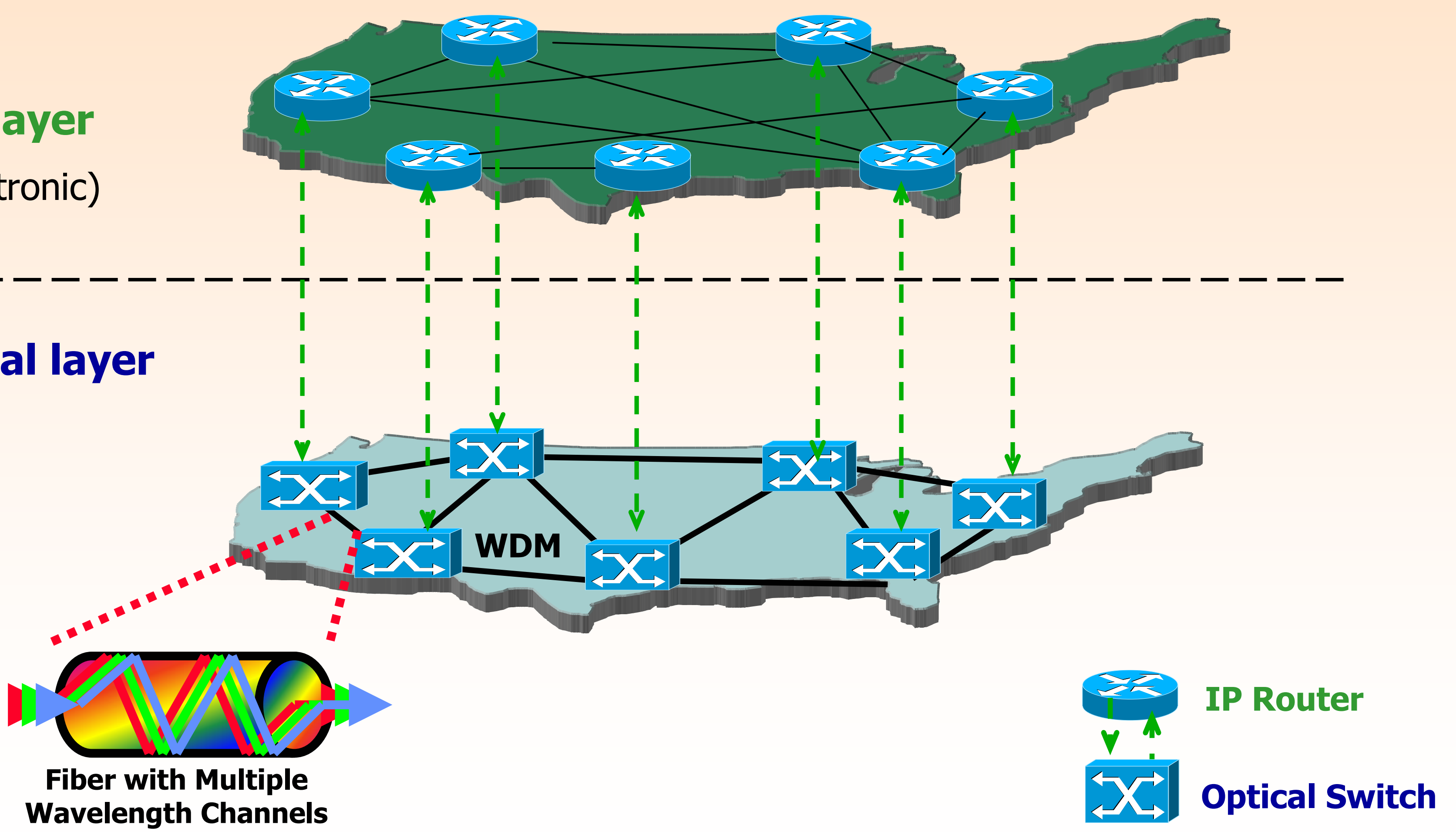


Layered Optical Network Model

IP layer

(Electronic)

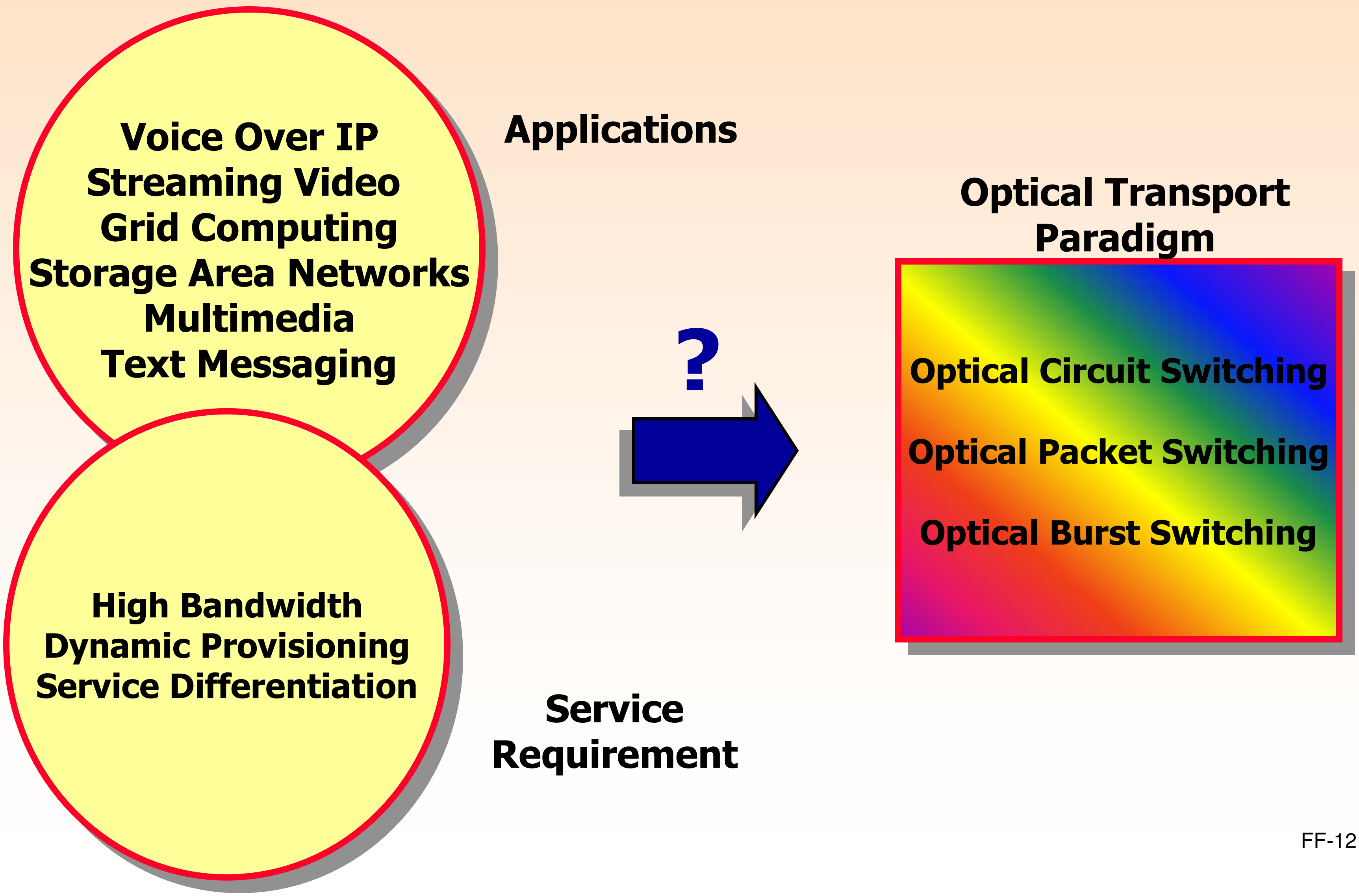
Optical layer



Future Optical Network - Enabling Technologies and Applications

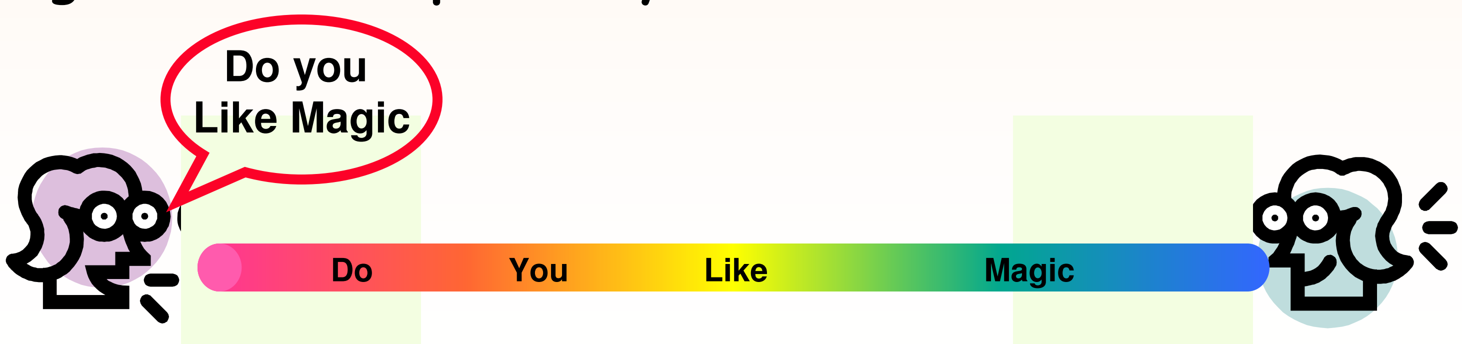
- WDM technology
  - More wavelengths in a single fiber (DWDM)
- Switching technology
  - Optical circuit switching
  - Optical packet switching
  - Optical burst switching

Future Optical Network -
Enabling Technologies and Applications

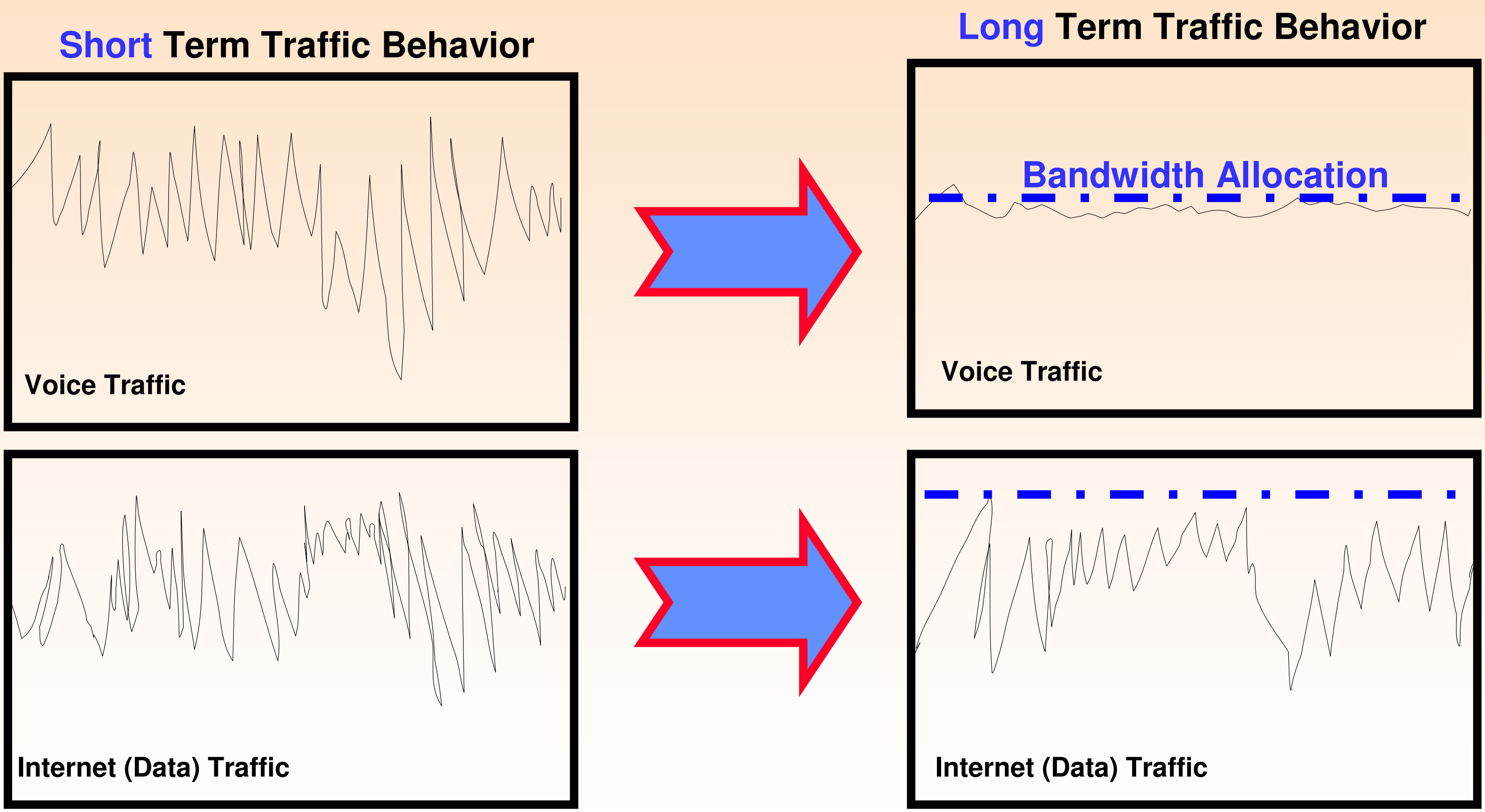


Optical Circuit Switching

- For each request a circuit is set-up
  - Static allocation of bandwidth for the entire duration of the connection
- Advantage:
  - Suitable for smooth traffic (Voice)
  - Reliable as long as the circuit is established
- Disadvantage:
  - Inefficient for bursty traffic (Data)
  - Long circuit set-up latency



Traffic Burliness: Voice and Data

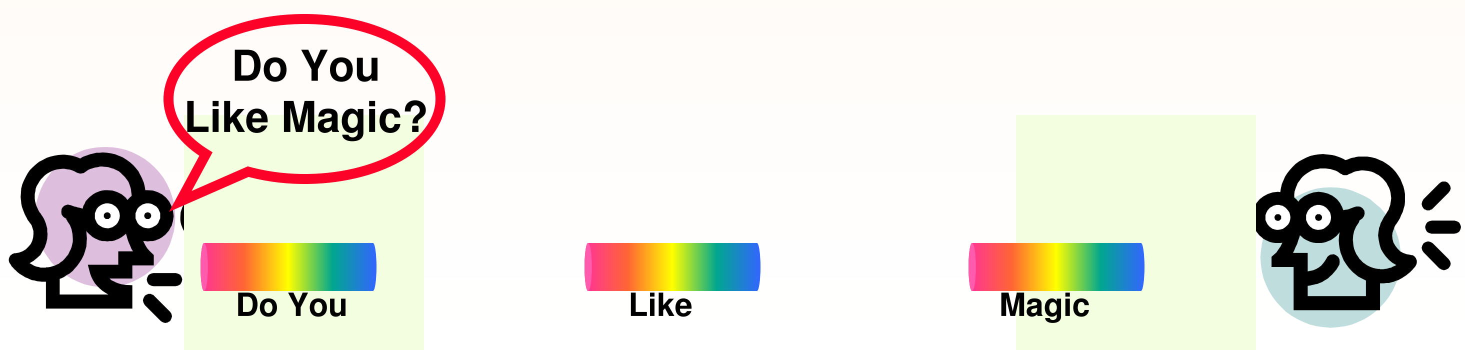


Data tends to be **bursty &** Static bandwidth allocation is **not** efficient

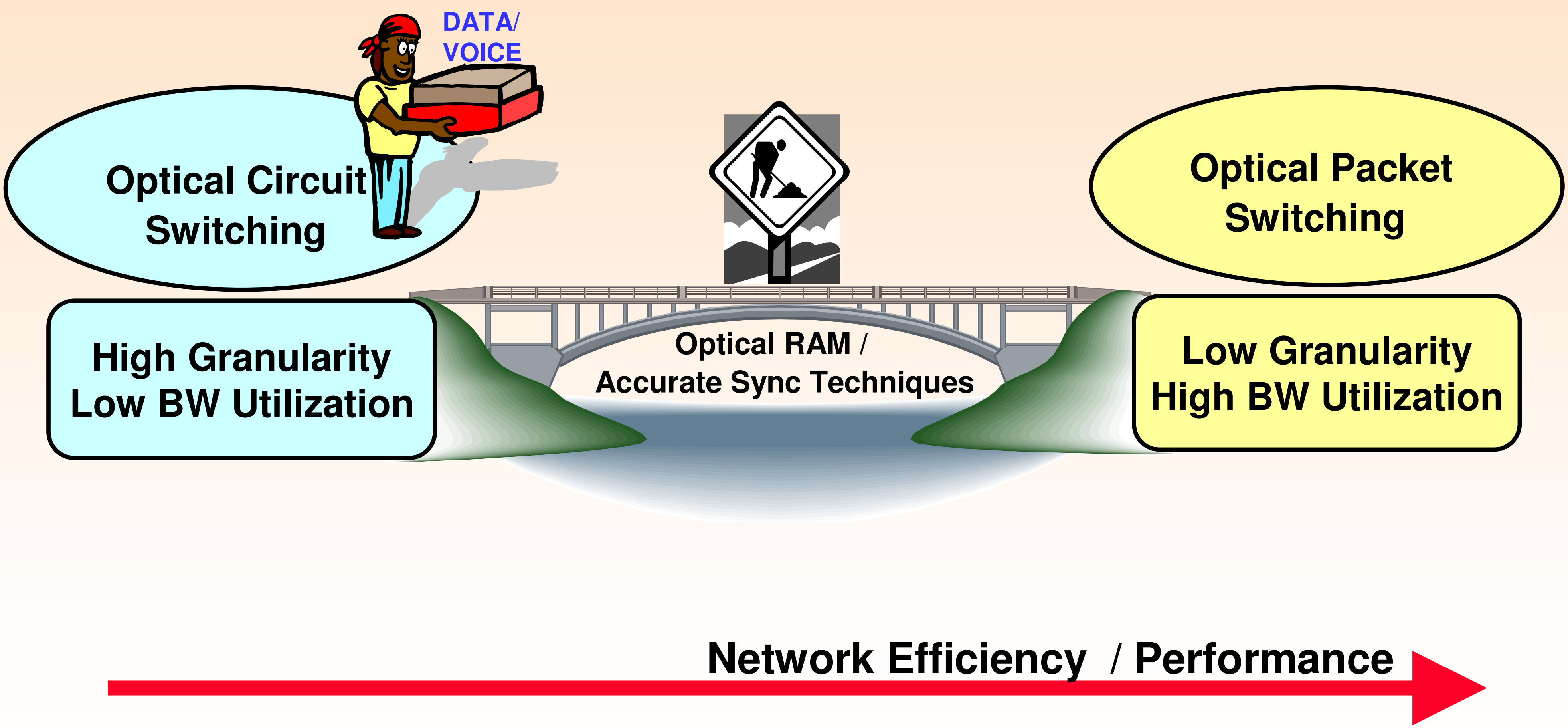
All-optical Packet Switching

UTD

- Data is encapsulated in one (or more) photonic packet
  - A photonic packet contains a header and the payload
- Packet is processed all-optically at each node
- Advantages:
  - Suitable for bursty traffic
  - Statistical multiplexing of data
- Disadvantages:
  - Requires optical buffering
  - Requires packet synchronization



Advancing Toward Optical Packet Switching

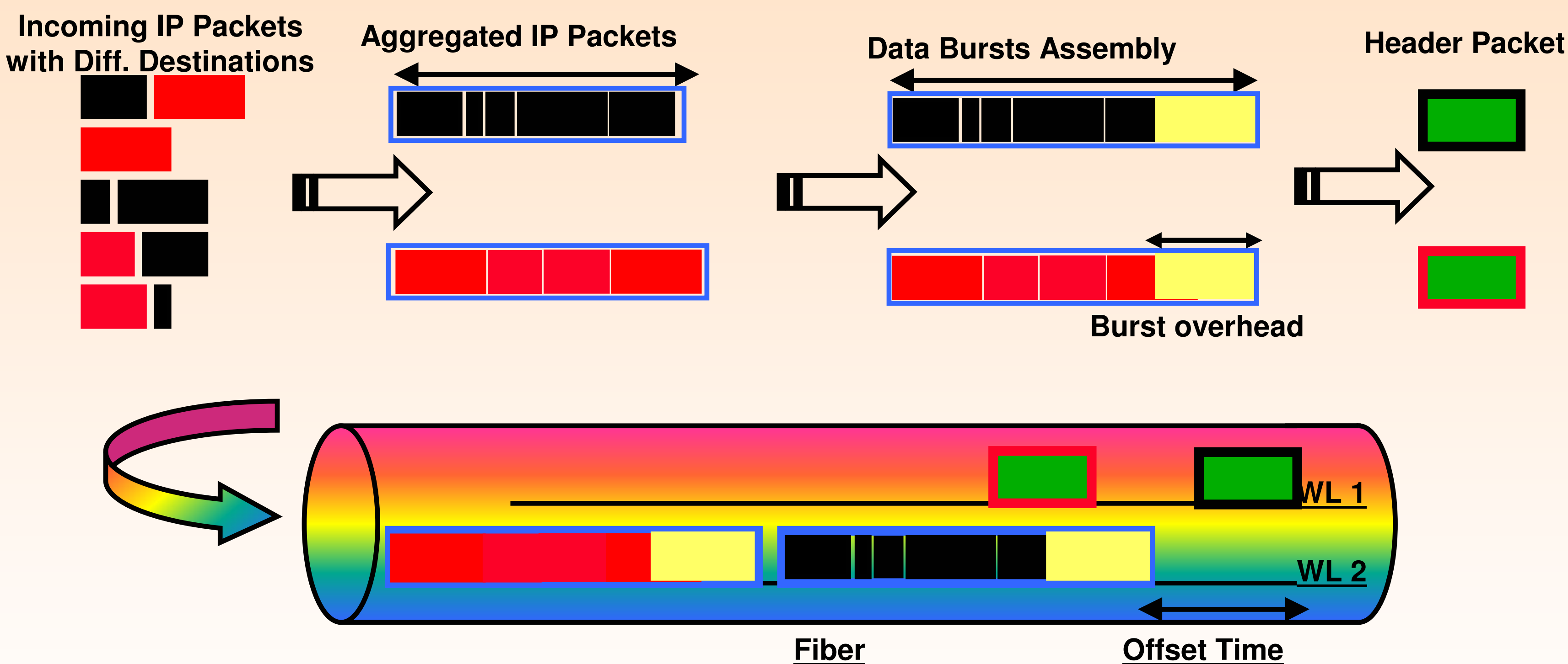


Optical Burst Switching

UTD

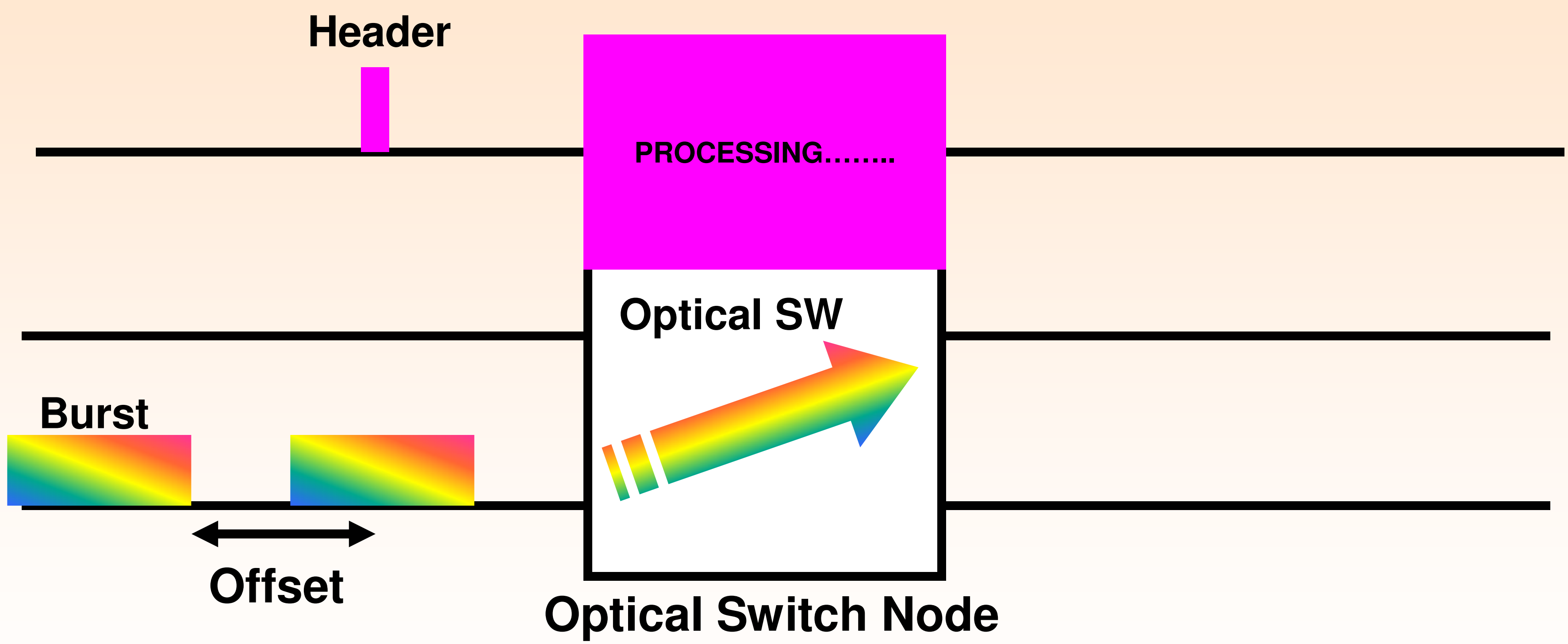
- A hybrid between electrical and optical technology
- Basic idea
  - Encapsulating IP packets into larger packets called *bursts*
  - Control and data planes are separated
    - The control header packet is processed electronically
    - The data burst is processed optically
  - Assigning dedicated channels for header packets (Out-of-band)
  - Dedicating an offset time between the header and data burst

Optical Burst Switching – Basic Idea



- Headers are processed electronically
- Data bursts are processed optically

Optical Burst Switching – Basic Idea



Data burst passes through the Switch all-optically

Optical Burst Switching –
Potential Advantages

- No *fine* optical buffering (optical RAM)
  - Fiber delay lines can provide sufficient optical buffering
- Relaxed synchronization requirements
- Electronic processing of header packets
  - Possibly at a different rate!

OBS utilizes the burst concept in optical domain!

OBS vs. Others Switching Technologies

Optical Transport Networks	Bandwidth Utilization	Traffic Adaptability	Latency (set-up)	Over head	Optical Buffer Requirements	Data Loss
Optical Circuit Switching	Low	Low	High	Low	None	Low
Optical Packet Switching	High	High	Low	High	High	Low
Optical Burst Switching	High	High	Low	Low	Low	High

Traffic Adaptability: such as burtiness

Overhead per unit of data

Source: K. Dolzer

OBS Feasibility and Applications

UTD

- Data types handled by OBS
  - Afford random loss
  - Tolerate some delay
- Applications of OBS
  - Grid computing
  - Bulk data transfer
  - Distributed data
  - OBS over ring topology

- Non-optical applications of burst switching
  - Satellite communication
    - Slow processors; limited memory
  - Transmitting control signals over the backplane

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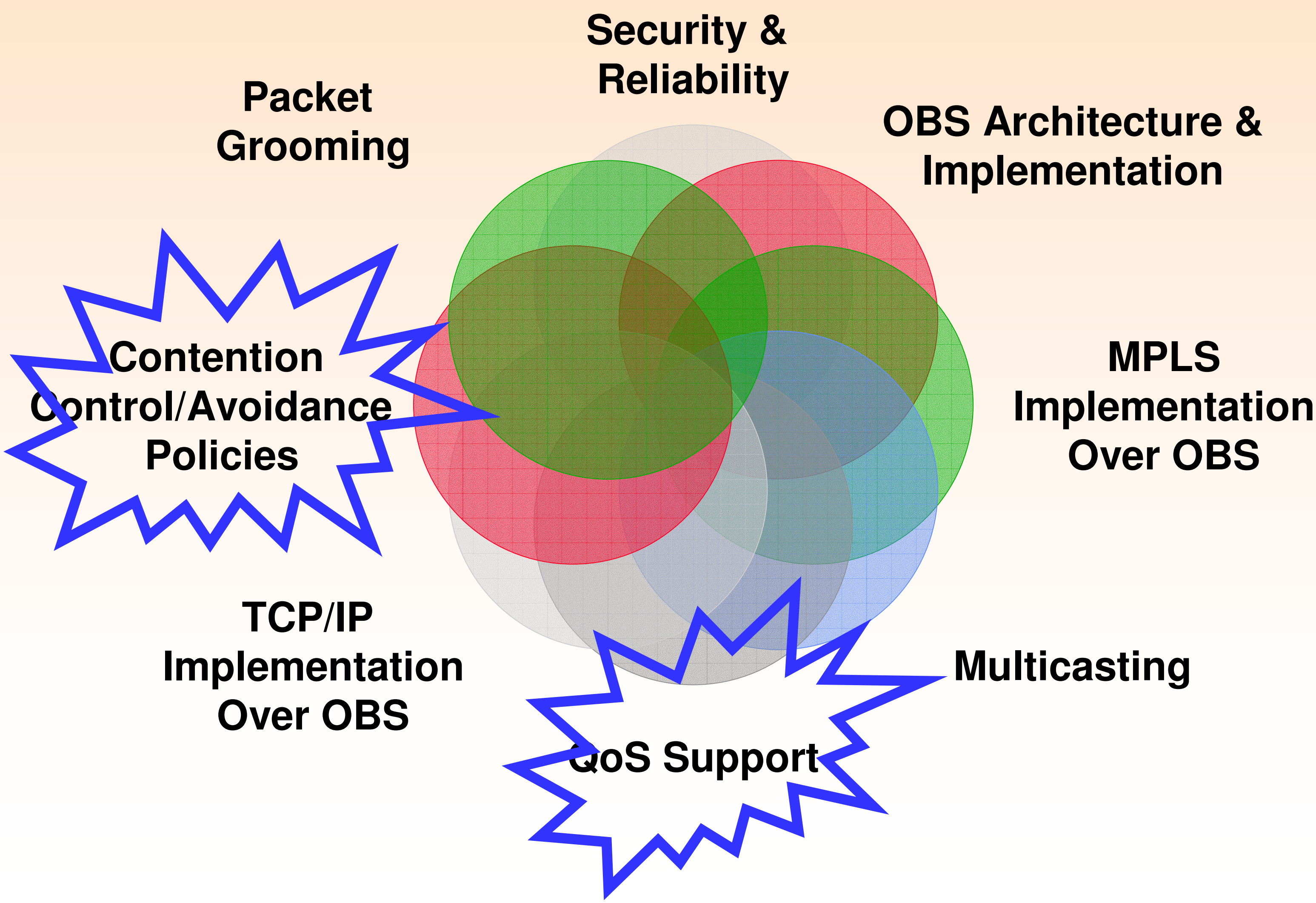
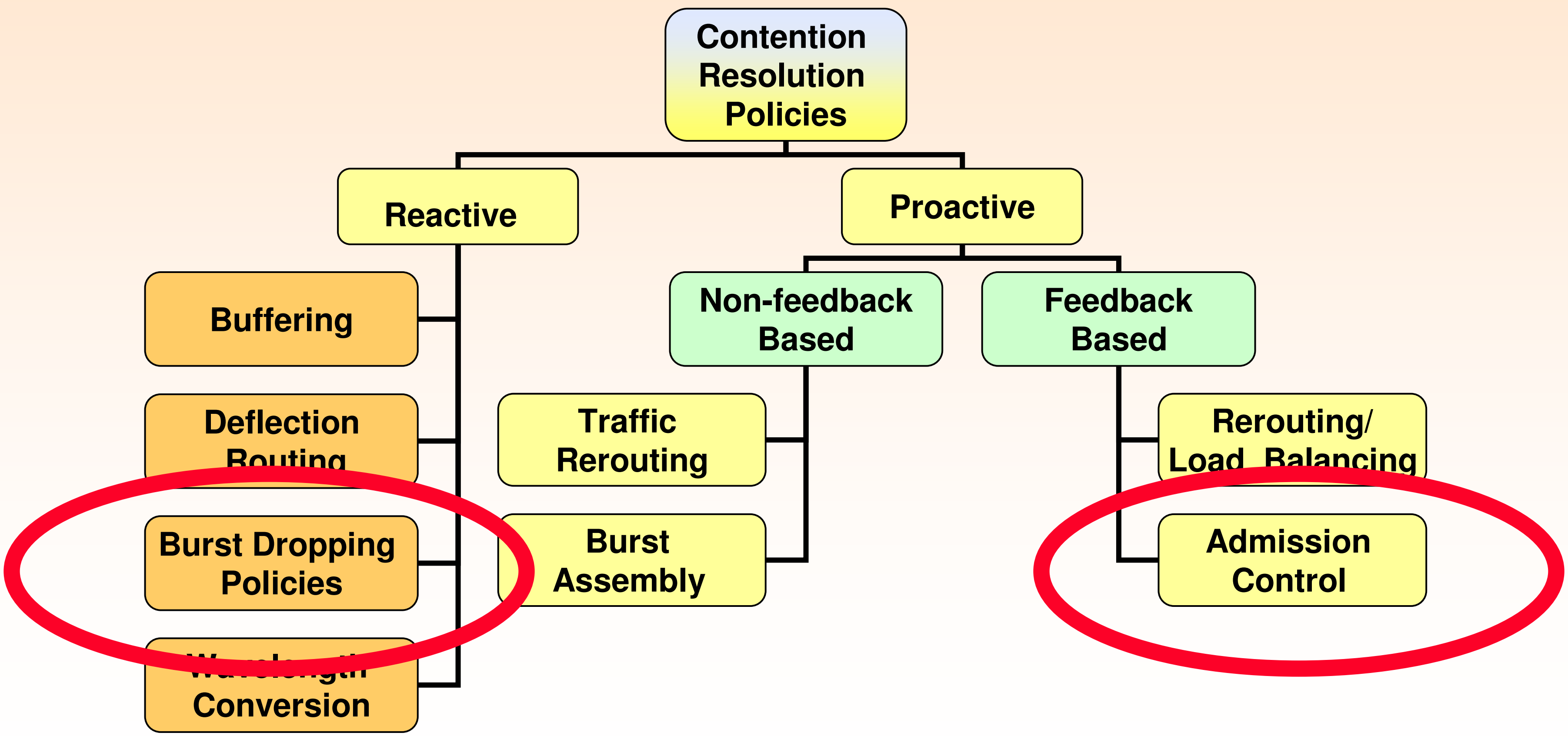
Optical Burst Switching –
Challenges and Issues

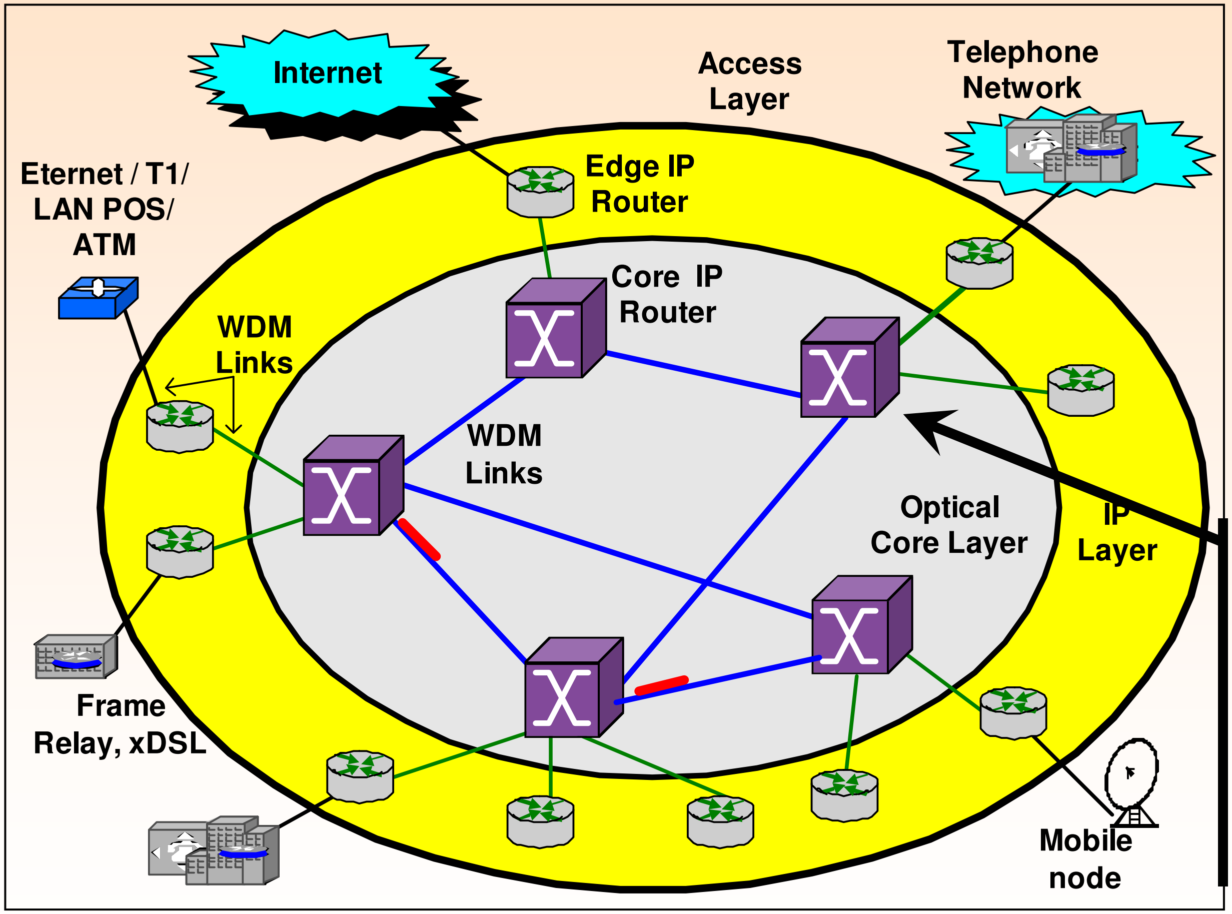


Contention Policies in OBS

- Contention resolution techniques
  - Resolution of contention between data bursts



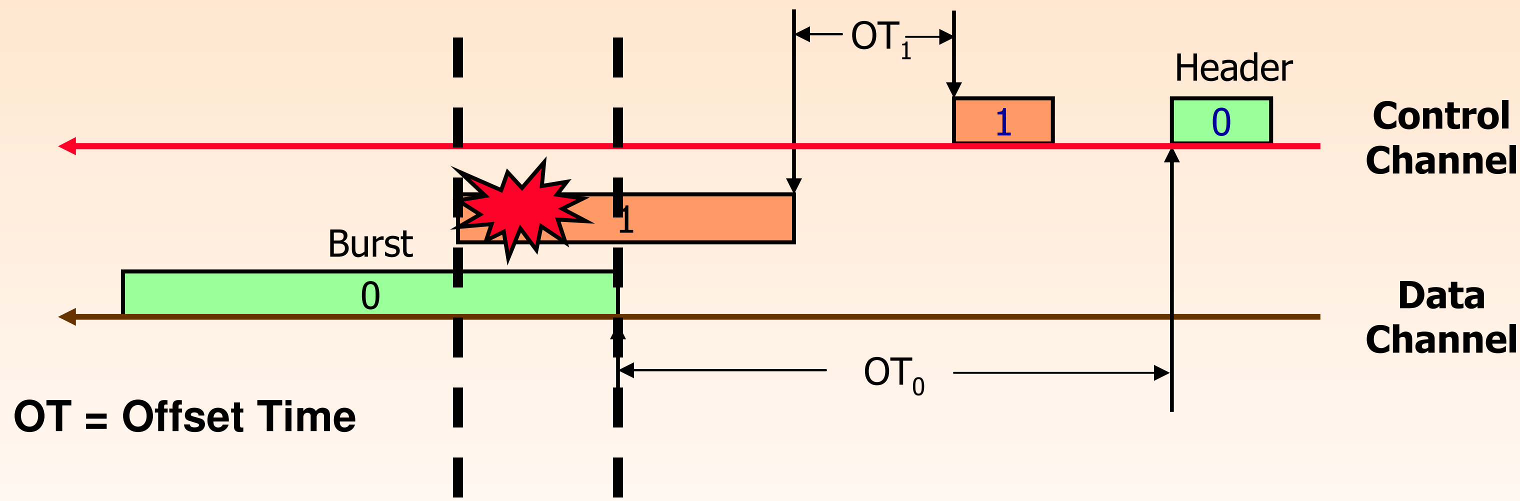
Optical Burst Switching Network
Components



How Do We Resolve Data Burst Contention in the Core?

Data Burst Dropping Policy

❑ What is Contention?



❑ Existing dropping policies

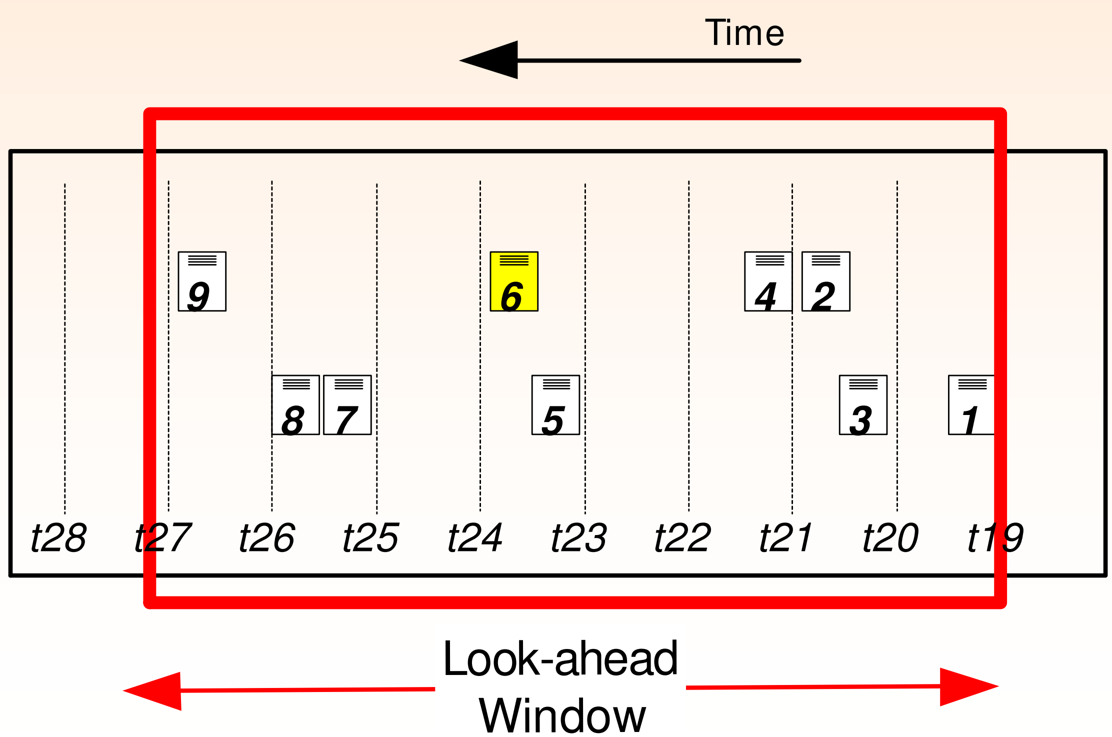
- Latest Drop Policy (drop the latest arrival)
- Segmentation (drop overlapping segments)

Look-ahead Contention Resolution

- Implementing with any signaling protocol
- Enabling service differentiation
- Takes advantage of separation between data bursts and their headers
  - Provides longer view of arriving data bursts
  - Offers extended scheduling information

Simple Example
Using Look-ahead Contention Resolution

- Collect all incoming header packets within a look-ahead window W slots long
- W >= 2 x (average burst size)



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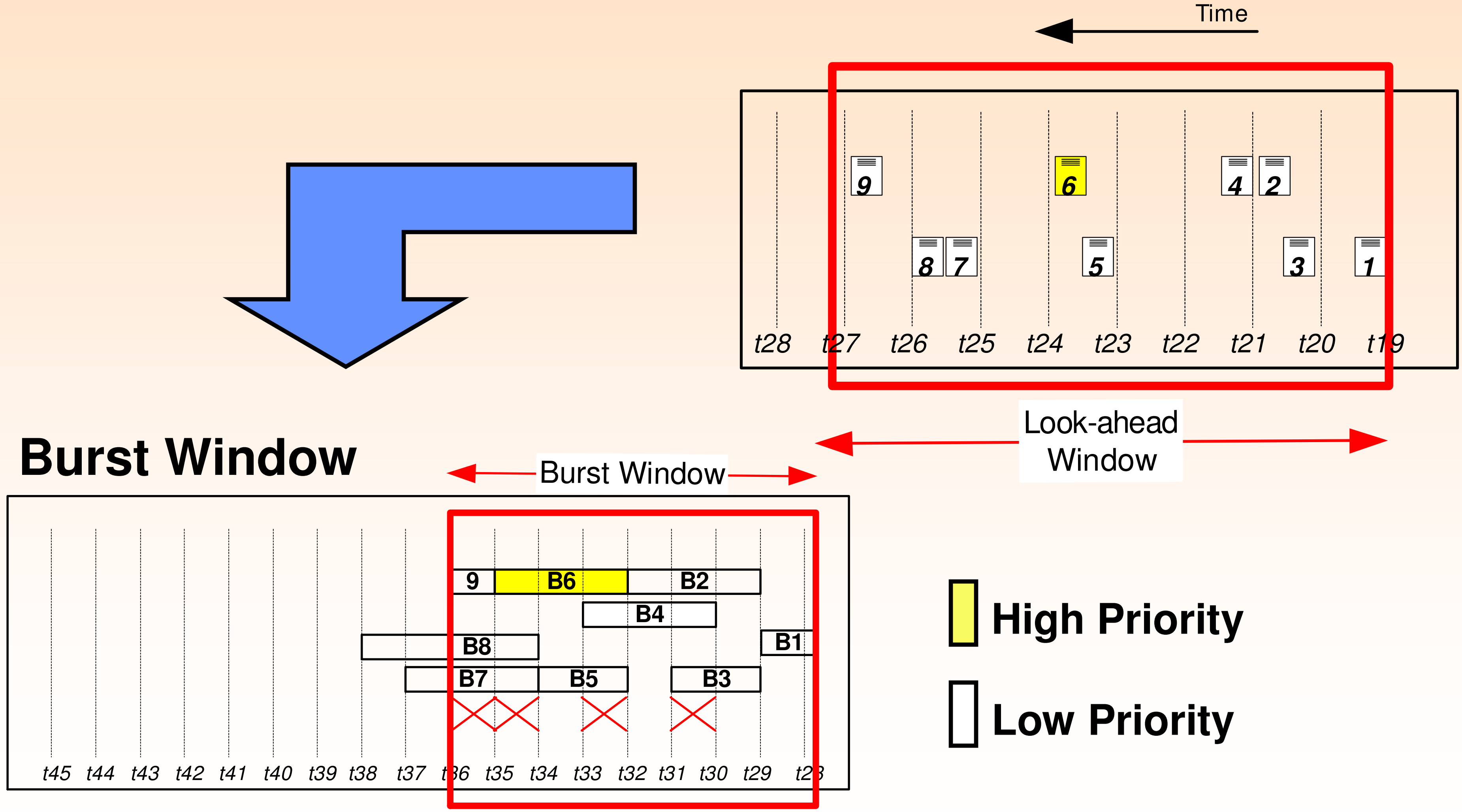
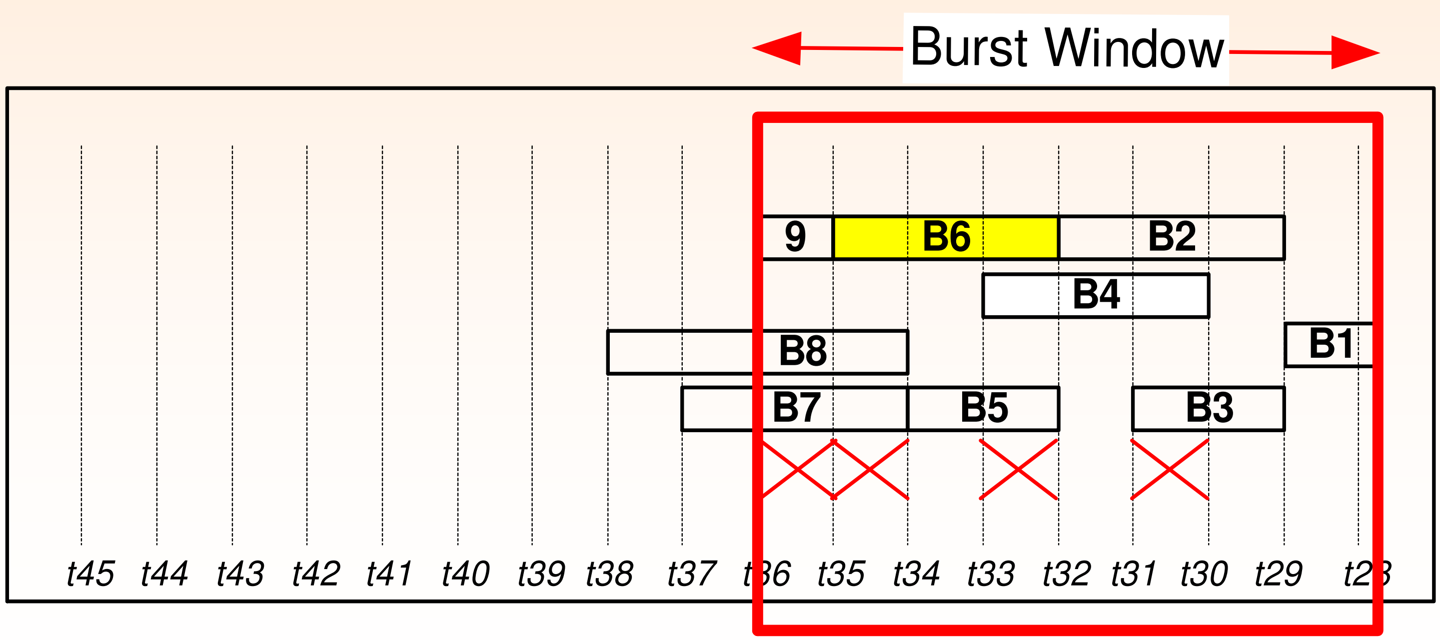


Simple Example
Using Look-ahead Contention Resolution

- **Determines contention slots**
- Decides which data burst(s) to drop in order to minimize burst loss



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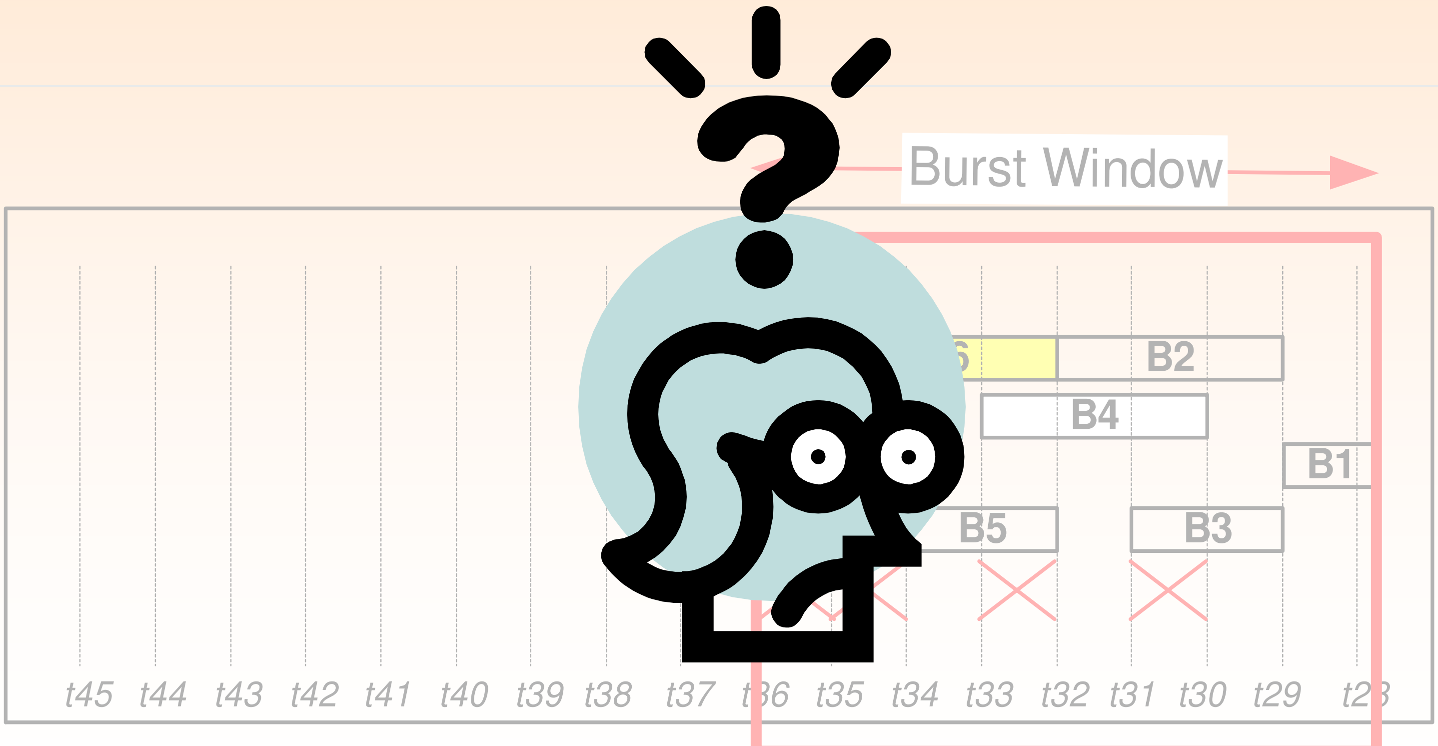
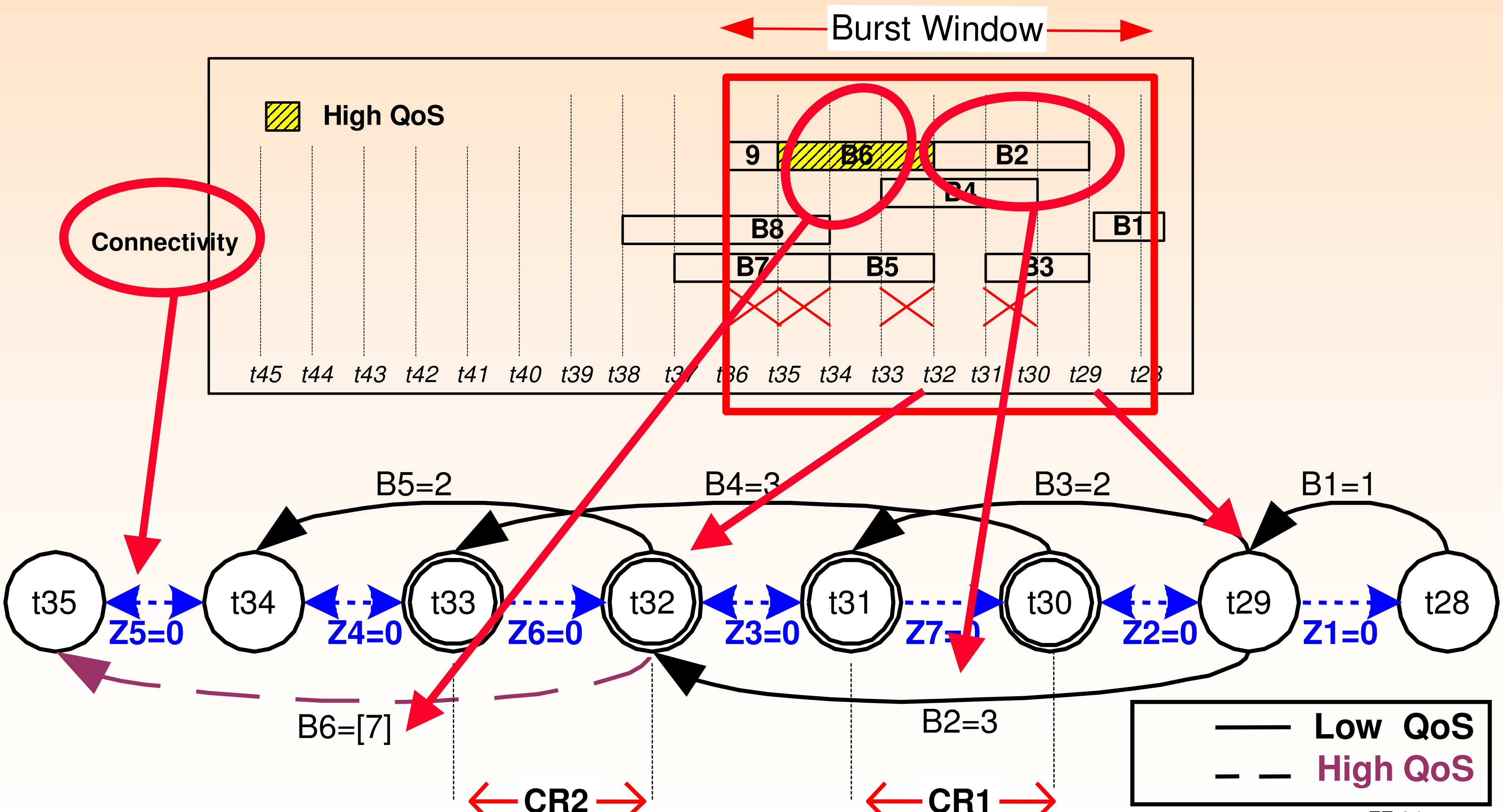


Look-ahead Contention Resolution
Dropping Section

- Create ***auxiliary directed graph***
  - Nodes represent starting and ending times of bursts
  - Arcs represent data bursts
  - Weights indicate data bursts' durations
  - Extra weight dedicated to arcs representing high priority bursts
- Ensure the graph is ***connected***
- Apply the ***shortest path algorithm*** from the start of the FIRST to the END of the last contention slot in the burst window
- Edges on the shortest path represent burst(s) to be dropped

Look-ahead Contention Resolution



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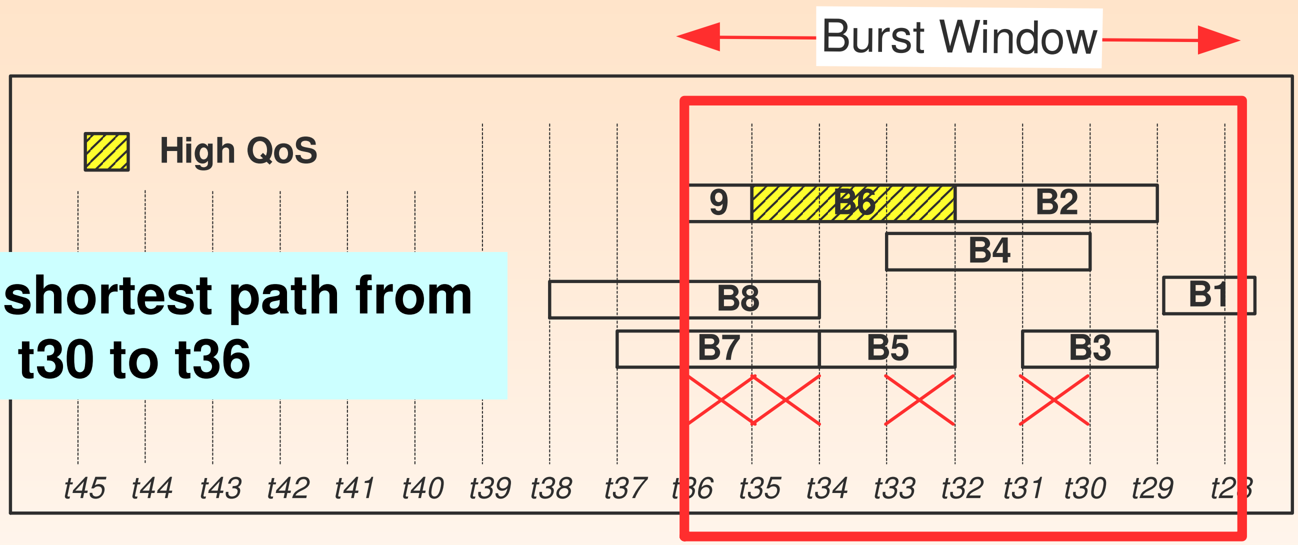
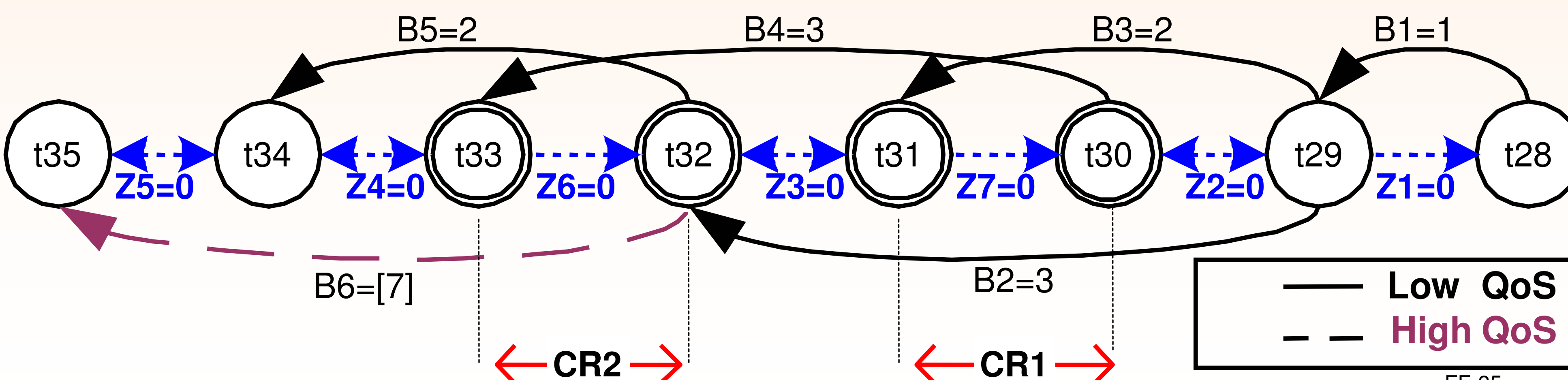
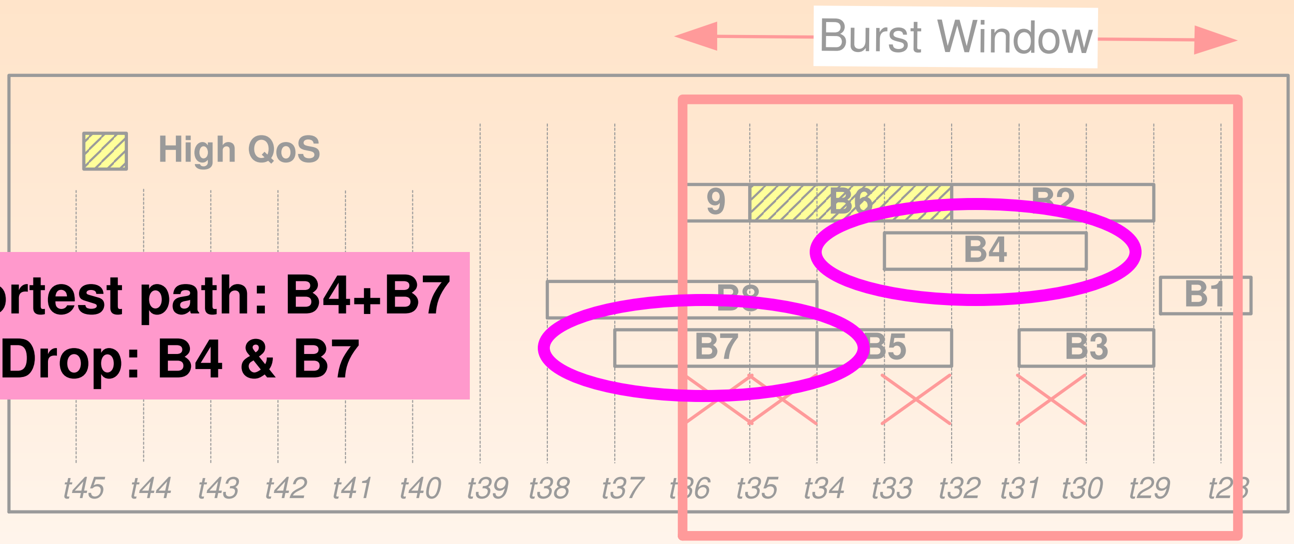
Look-ahead Contention Resolution



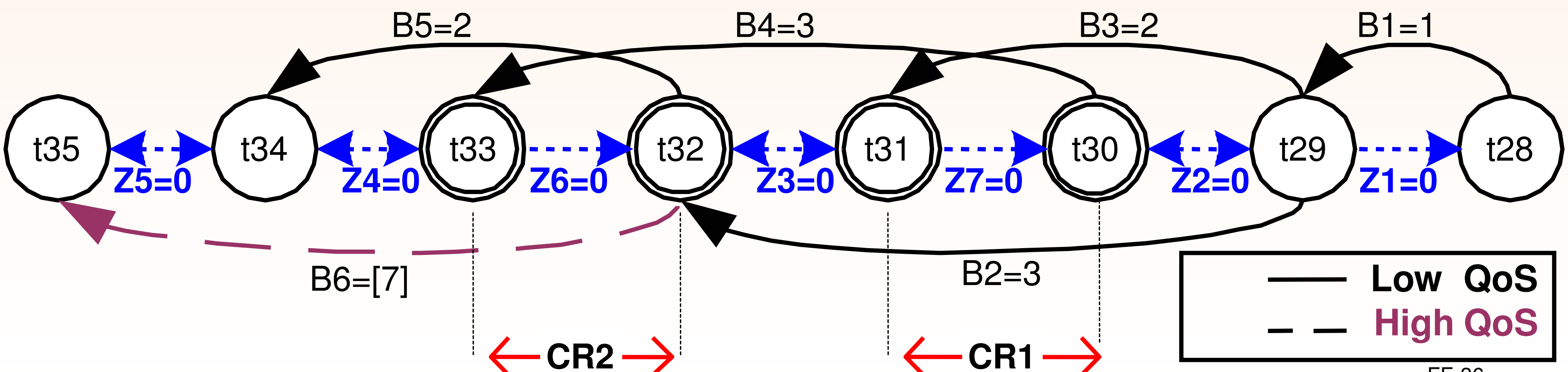
Find the shortest path from t30 to t36



Look-ahead Contention Resolution



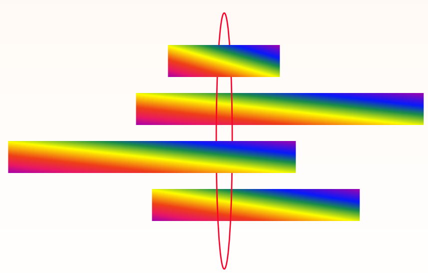
Shortest path: B4+B7
Drop: B4 & B7



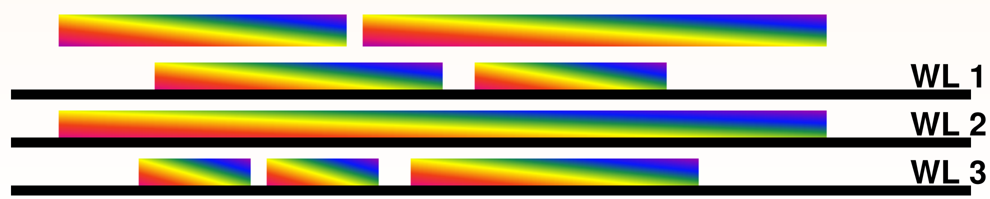
FF-36

Analyzing Look-ahead Contention Resolution

- The *general* problem of choosing which bursts to remove is NP-complete
  - Using graph theory and independent sets
- An efficient polynomial-time algorithms can be developed for special cases
  - The overlapping degree of each burst is the same
  - The contention degree is limited to one



Overlapping degree = 4



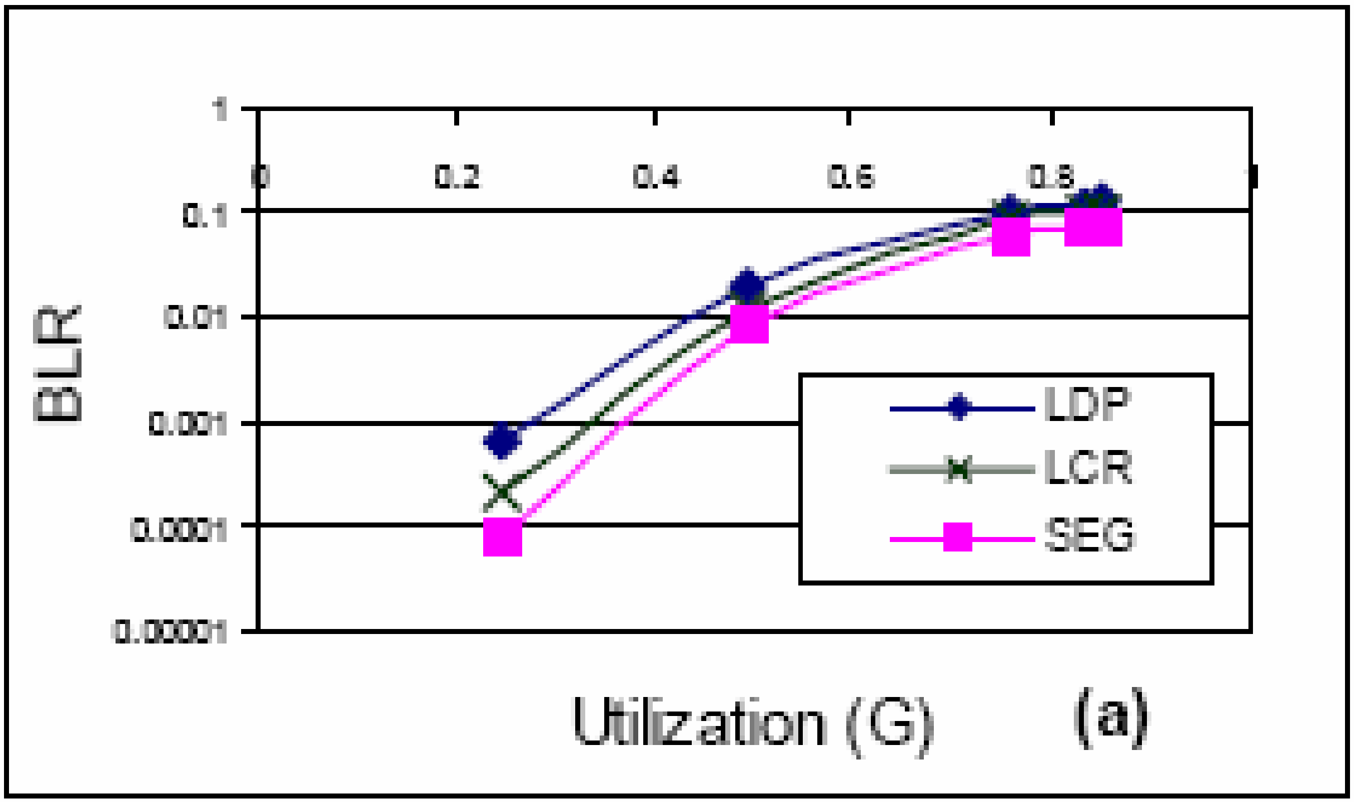
W = 3; Contention degree = 1

Look-ahead Contention Resolution - Variation

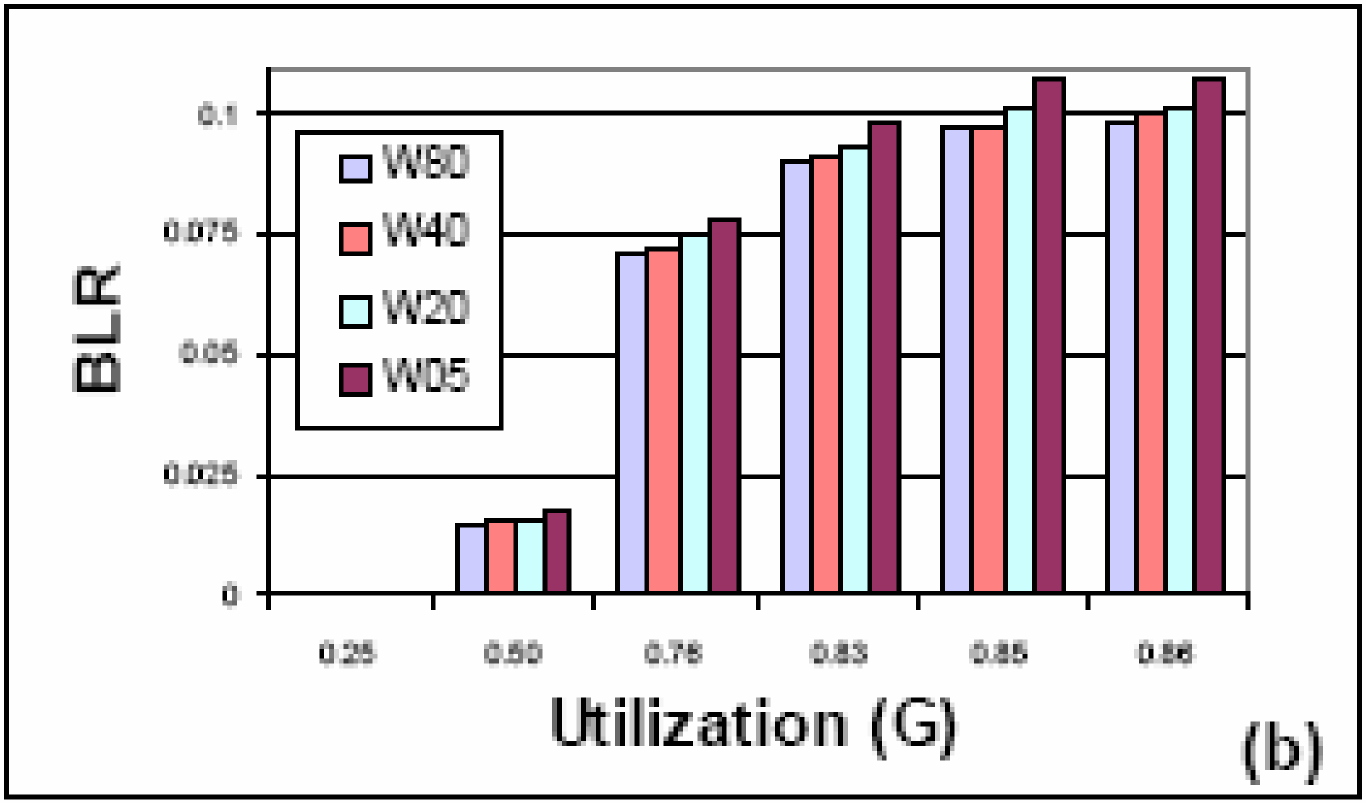
- Called *shortest drop policy*
- Special case of the Look-ahead Contention Resolution
  - W=1 (single slot)
- Header packets processed as soon as they are received
  - Lowering processing delay
- Bursts with highest priority and longest length preempt the rest

Performance Evaluation
Blocking Probability

BLR: The chance that a burst is blocked



Performance Evaluation
Window Size impact

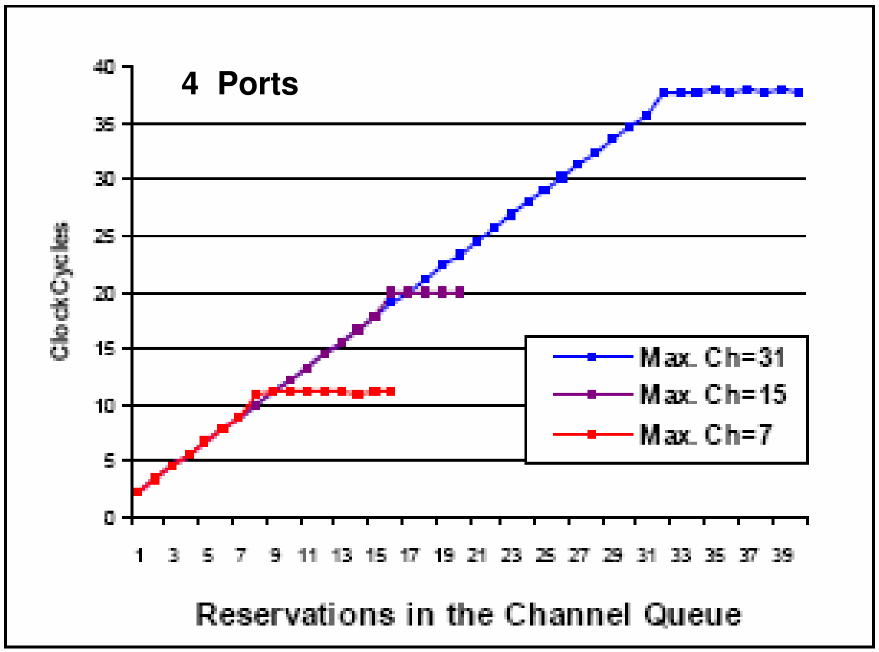


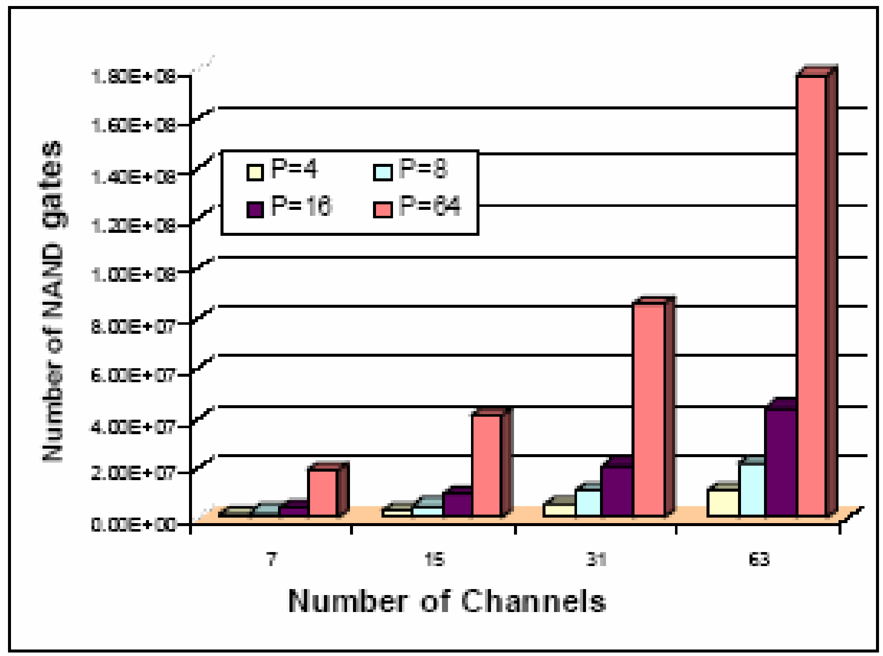
Implementation – Shortest Drop Policy

- Implemented on Altera EP20k400E FPGA
  - 2.5 million gates
  - Maximum clock rate of 840 MHZ
- Designed using VHDL code
- Tested, verified, and synthesized
  - Cadance (NcSim)
  - Quartus II

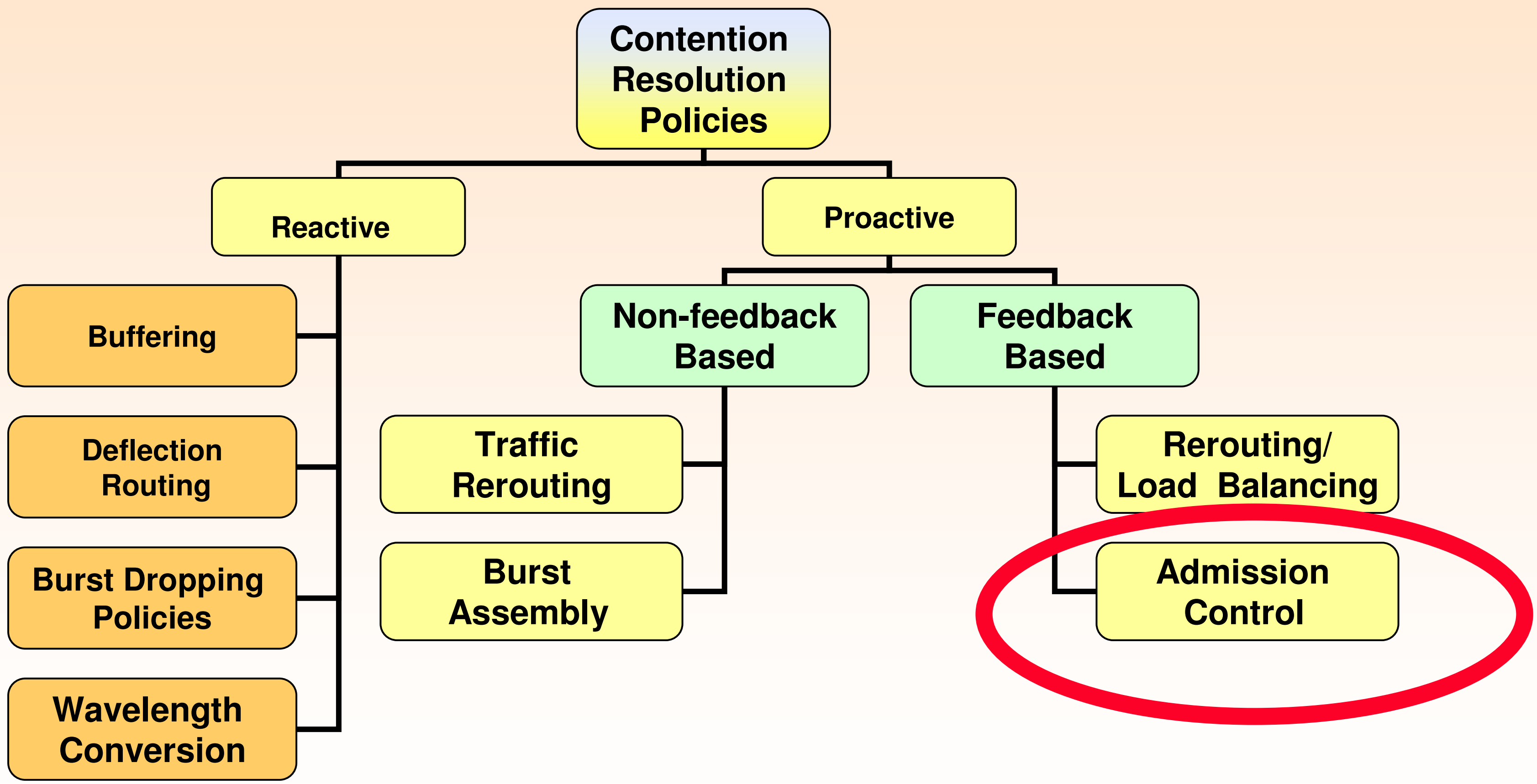
Testing hardware scalability of the algorithm in terms of size and speed

Hardware Performance – Shortest Drop Policy





Contention Policies in OBS



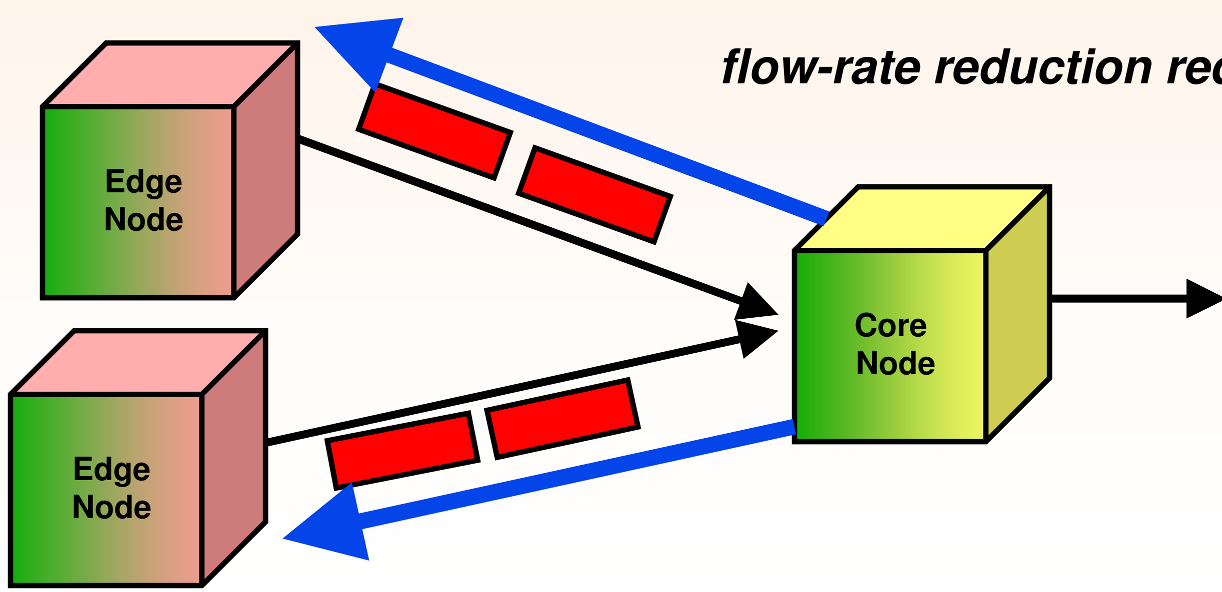
SFC Feedback-based Contention Avoidance – Major differences

UTD

- Source Flow-rate Control (SFC)
- Existing feedback-based mechanisms
  - Focus on rerouting or multiple retransmission
- Our proposed feedback-based mechanism
  - Flow-rate control
  - Loss-based system rather than a queue occupancy system (no buffers)
  - Feedback signal are sent to the source from the congested nodes (not end nodes)
  - Additive increase / multiplicative decrease

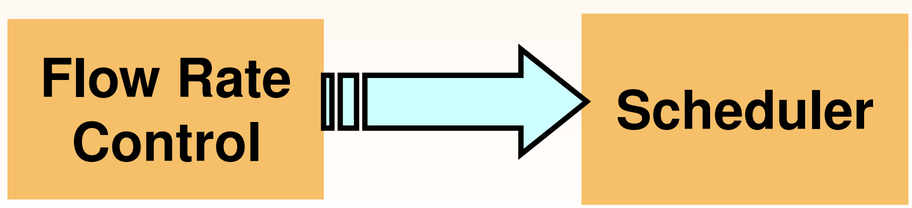
SFC Feedback-based Contention Avoidance – Basic Idea

- The core sends feedback signals to edge nodes
- Feedback signals explicitly request for flow-rate change on a link
- Edge nodes adjust their burst flow rate through admission control



SFC Feedback-based Contention Avoidance – Edge Node Functionalities

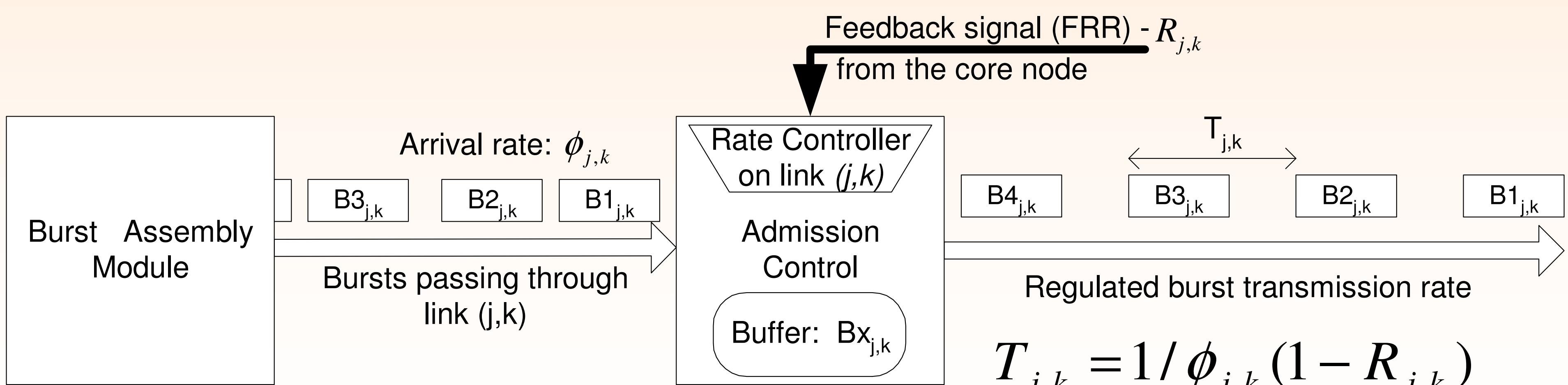
- The source edge node receives all feedback signals ($R_{j,k}$)
- It performs two basic operation
  - Determining the data burst flow rate on the congested link (j,k)
  - Scheduling data bursts



Edge Node's response to the feedback

SFC Feedback-based Contention Avoidance – Flow Control Rate

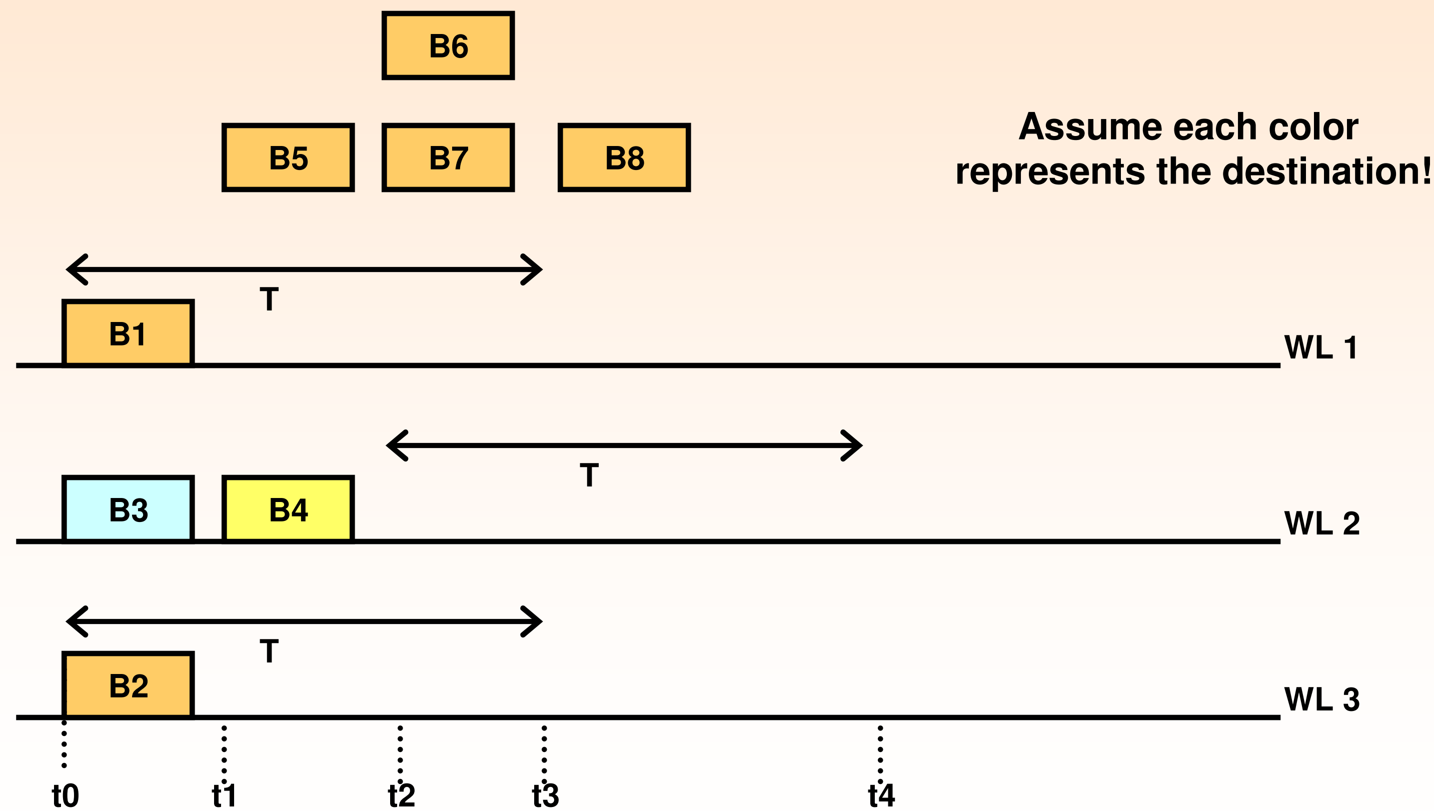
- The core measures the average load no each port
  - Increase the flow rate additively
  - Decrease the flow rate multiplicatively



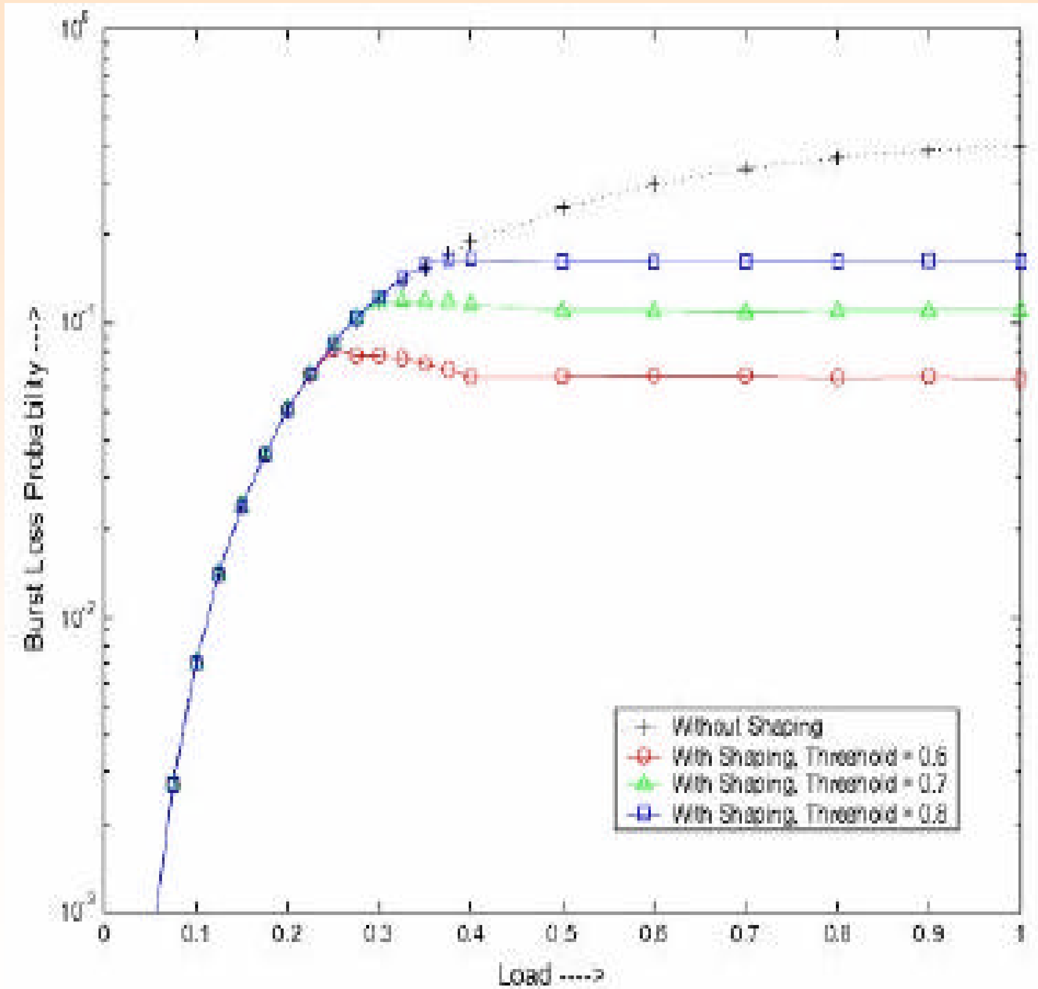
$$T_{j,k} = 1/\phi_{j,k}(1 - R_{j,k})$$

SFC Feedback-based Contention Avoidance - Performance

- Data bursts subject to admission control are scheduled on the latest available wavelengths



SFC Feedback-based Contention Avoidance - Performance



OBS Network Risks

- OBS is a highly decentralized network
  - Reliability concerns
  - Security risks
- Security Risks
  - Deny-of-Service
    - sending more requests than the node can handle
  - Unauthorized access
    - Denying access to the attacker
- Basic Issues
  - Data integration: ensuring information has not been altered by unauthorized or unknown means
  - Confidentiality: keeping information secret from all but those who are authorized to see it
  - Message authentication: corroborating the source of information
  - Signature: binding information to an entity
  - Timestamping: recording the time of creation or existence of information.

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- Basic Issues

Data integration | Con-fidentiality | Authen-tication | Signature | Time stamping

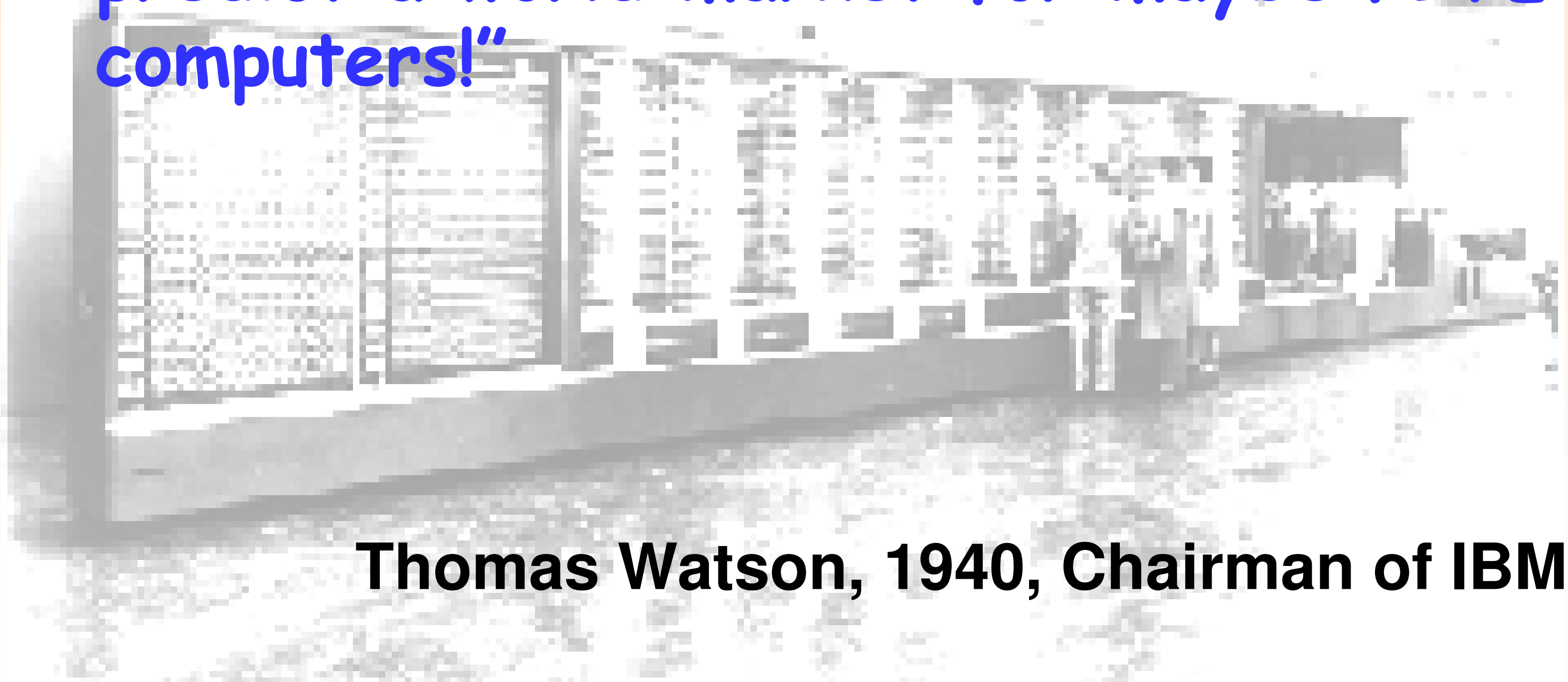
OBS Security Risks

OBS security model

- Separating data and control planes
  - Developing different authentication techniques
  - Supporting Hop-by-hop as well as end-to-end encryption
  - Implementing at both the edge and code nodes
- Supporting a comparable security level
- Providing a secure data integration
- Requiring simple administration

Transport security in OBS is an open research area

Concluding Remarks



"I don't really foresee any commercial possibilities for COMPUTERS and I predict a world market for maybe FIVE computers!"

Thomas Watson, 1940, Chairman of IBM

Mark I; brainchild of Howard H. Aiken; 1939-1944

Thank you!

For more information:

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