OPS: Optical Packet Switches

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Optical Network Testbeds Workshop 3

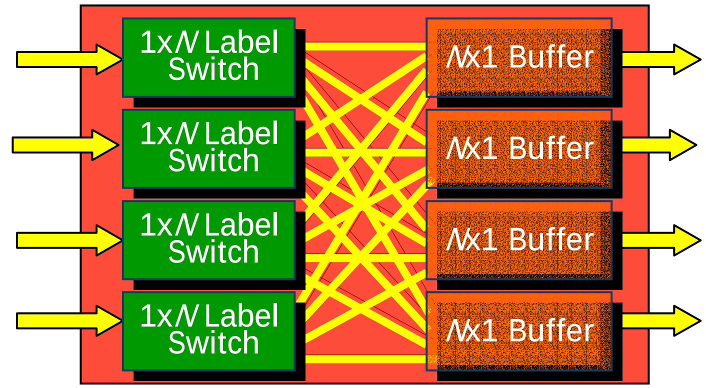
Why do we Need OPS?

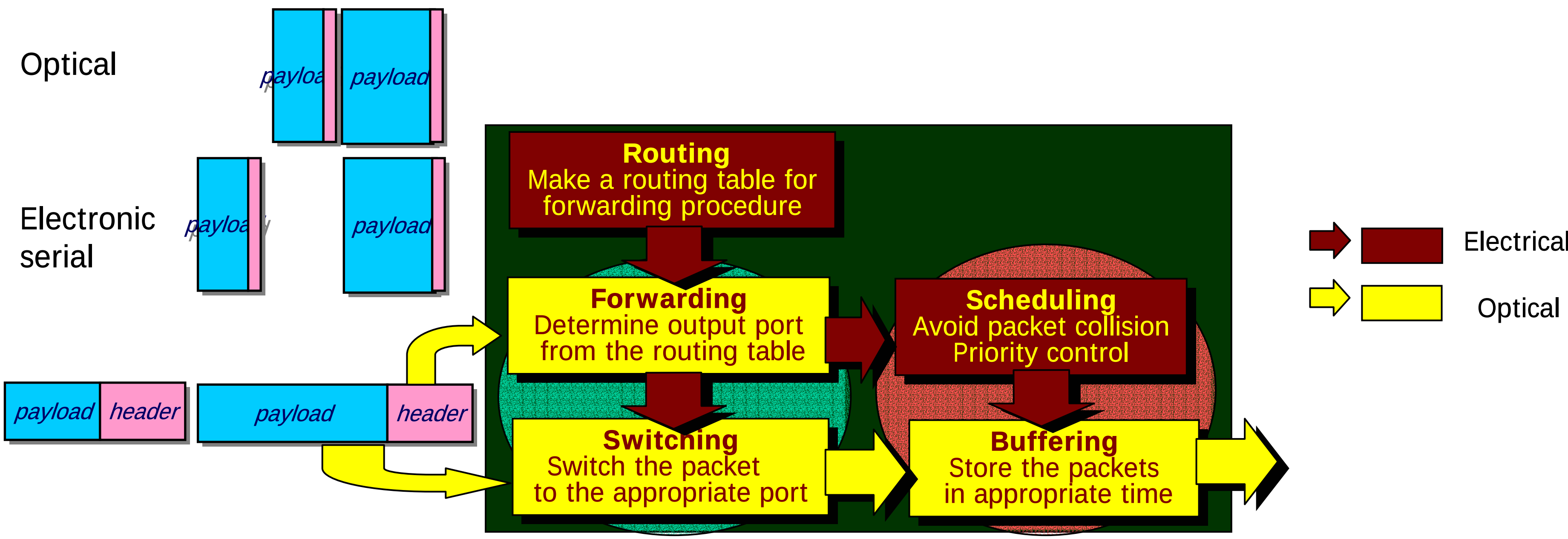
- Internet Traffic in Japan: approx. 500 Gbps
- Peta-bps backbone future: doubled per year ← 500 Tbps in 10 years
- Electronic packet switch
  - Year 2004: Throughput 640Gbps (16x40 Gbps)
- Lightpath networks
  - Need fully meshed connections/ feasible?
  - Need complex traffic engineering
  - Important technology for bandwidth-assured applications
- OPS networks
  - Provide extremely high-throughput
    - Much larger bandwidth for switching (> 40 Gbps)
    - O/E/O: 40Gbps → 64 x 622 Mbps bus, SERDES
  - May need MPLS-like control (labels can be merged)
  - Important to ubiquitous society

Optical Packet Switching

NICT

- Data-path is all-optical (No O/E/O)
  - Switch, Buffer
  - Increase data bandwidth
- Label lookup (i.e. forwarding)
  - Electronic parallel processing?
  - Optical processing





What should be Solved for OPS?

- OPS
  - Increasing number of ports of optical switch
    - Electronic: 16x16, 40Gbps → 640Gbps
    - Optical: 128x128, 160Gbps → 20.48 Tbps
      - 25 Waves → 500 Tbps
  - Increasing speed of label lookup and buffer management
    - Wire-speed operation
  - Increasing number of labels looked-up
    - Several thousands (New L2 possibility)
    - More (L3 switching)
  - Increasing buffer size
    - At least tens of fiber-delay-lines
  - Decreasing guard time between packets
    - Several nanoseconds
- OPS Monitor/Analyzer
  - Bit error / Optical packet error

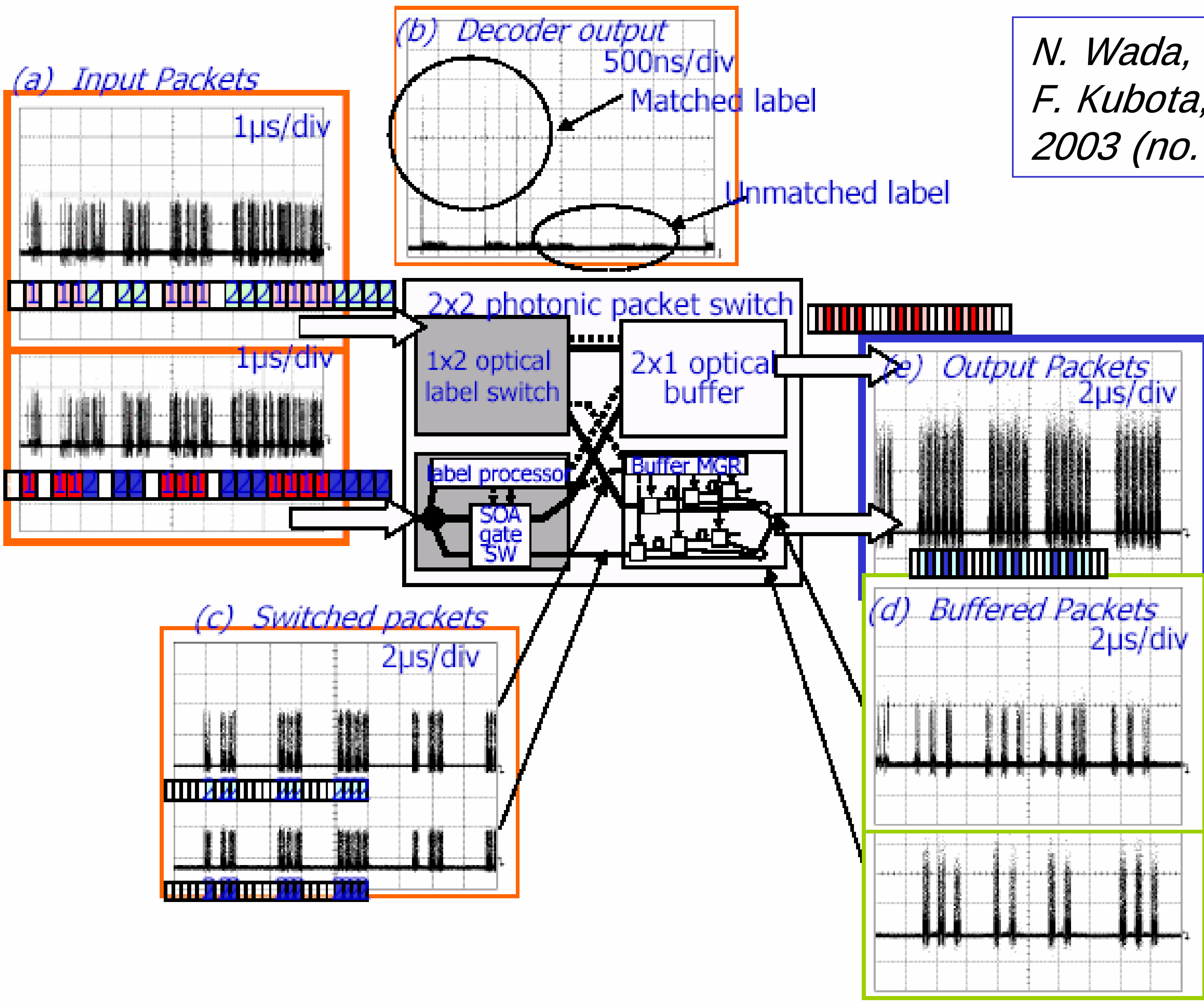
Under developing in NICT

Remaining Topics of This Talk

- OPS Prototype
- Optical label lookup
- Optical buffer
- Electronic buffer management

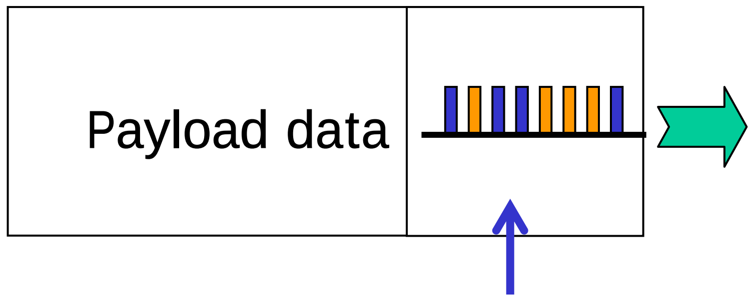
NICT's 40Gbps-based OPS Experiment

N. Wada, H. Harai, F. Kubota, OFC 2003 (no. FS7).



Optical Code based Ultra Fast Label Processing

Packet format



Replace to the optical code (label)

Optical label has different modulation format with payload data

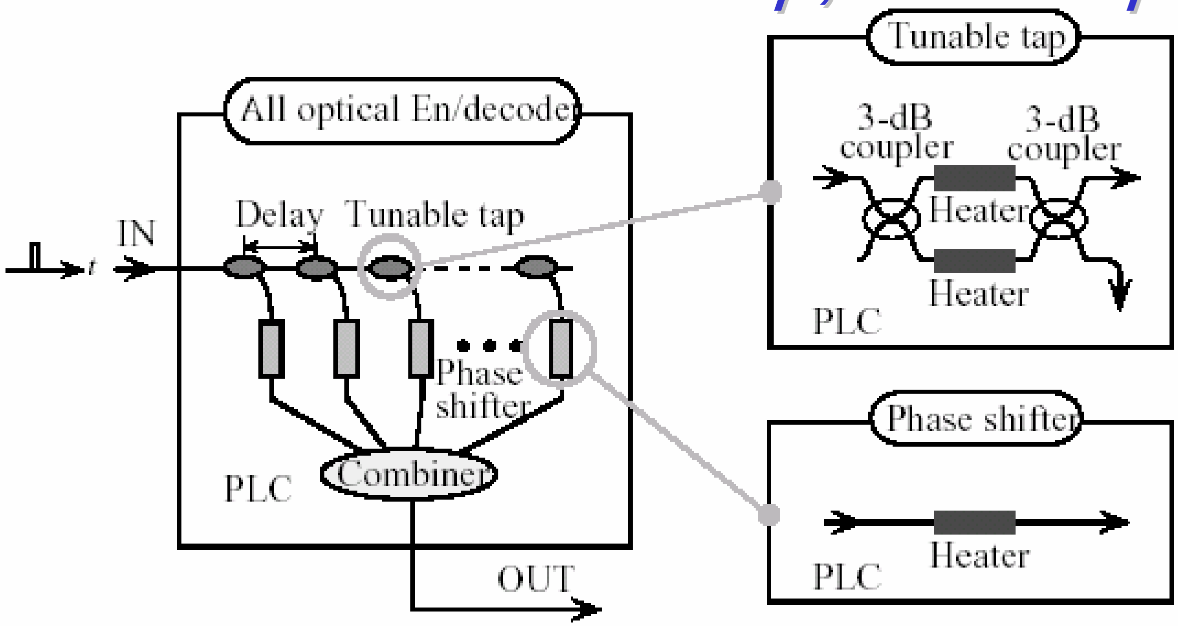
Optical label is physically distinguished from payload data

Optical hardware based label processing is available

Fully passive, ultra high-speed optical label processing

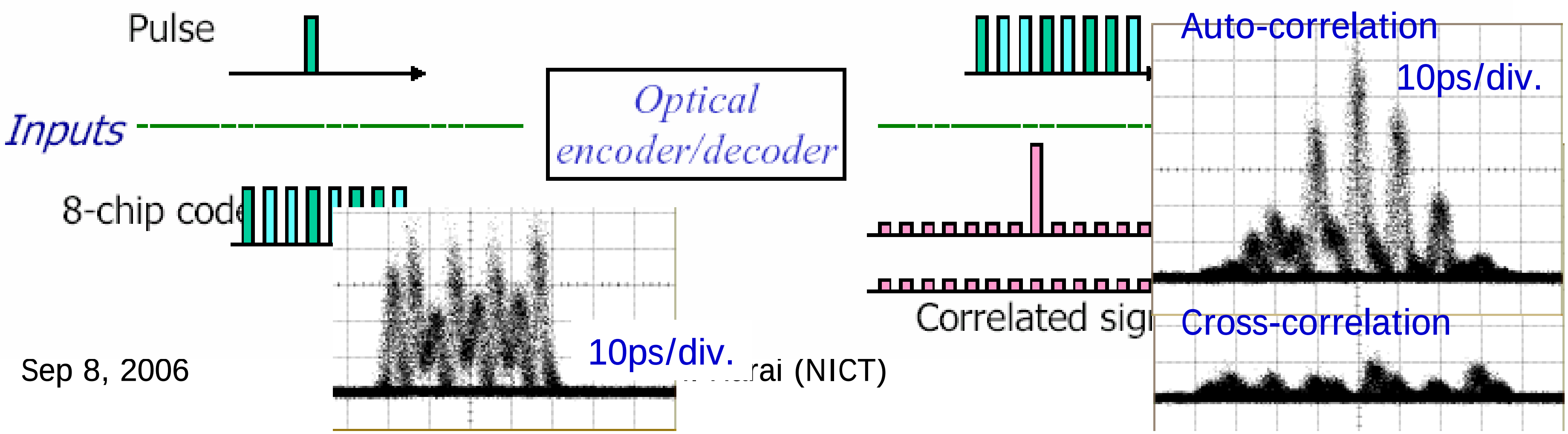
Time Domain Optical Code Processing --Measured Waveform at 8-chip, 200Gchips/s

NICT



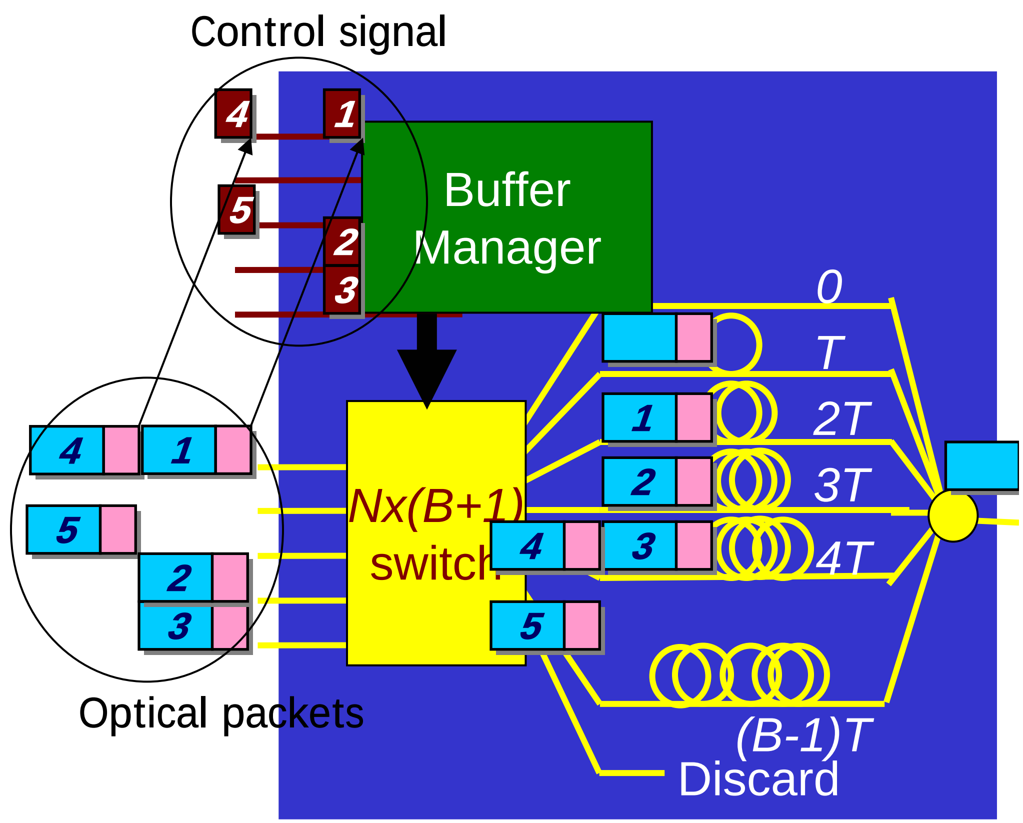
Ref.) K. Kitayama, N. Wada, IEEE Photonic Tech. Lett., vol. 11, pp. 1689—1691, Dec. 1999.

All optical encoding and decoding

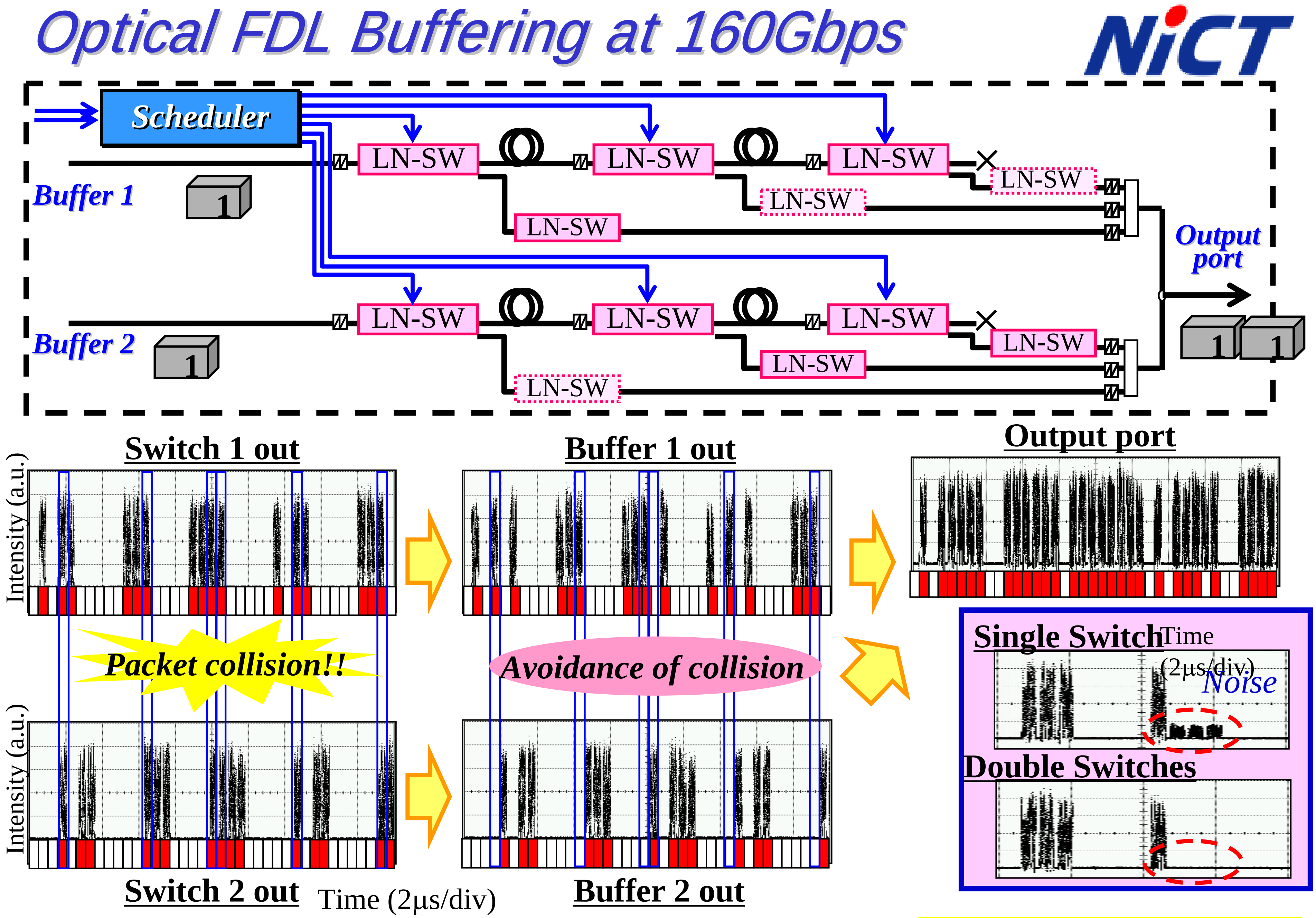


Optical Fiber-Delay-Line Buffer

- Different lengths of FDLs
- Need at least tens of FDLs
- H. Furukawa, H. Harai, N. Wada, N. Takezawa, K. Nashimoto, T. Miyazaki, "A 31-FDL Buffer Based on Trees of 1x8 PLZT Optical Switches," to be presented at ECOC 2006, no. Tu4.6.5, Sep 2006.



Optical FDL Buffering at 160Gbps



Source: N. Wada (NICT)

High-Performance Buffer Management for Optical Fiber-Delay-Line Buffer

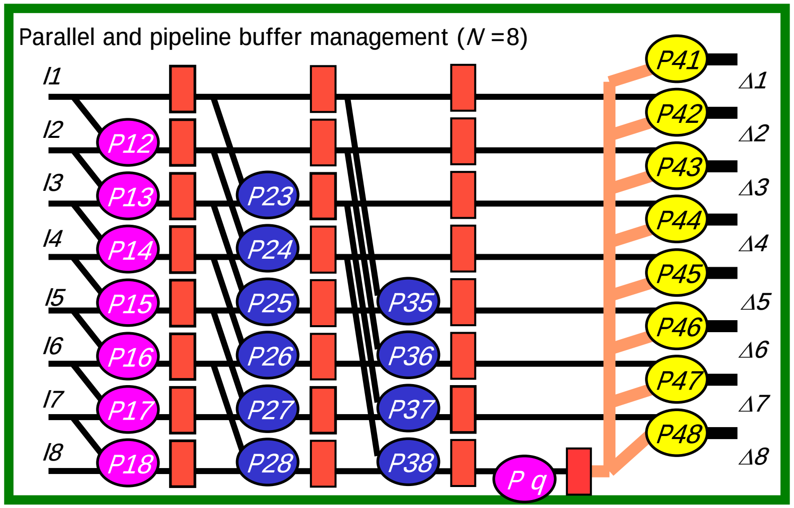
NiCT

- Establish practical-scale high-performance management for FDL buffer

(1) Develop buffer management by parallel and pipeline processing
- ◇ For number of ports, time complexity of each processor is O(1)
- ◇ Parallel expansion of sequential (i.e. round-robin) scheduling
- ◇ *N*-times higher throughput than sequential scheduling

(2) Confirm feasibility of support for 128x40Gbps packet switch by FPGA
- ◇ 8 times higher performance than ASIC based router (16x40Gbps)
- ◇ IP packet granularity (64byte or more; 10 Gpps), variable length

(3) Prototyping 8-port buffer management system



cf) H. Harai and M. Murata, IEEE/ACM Transactions on Networking, Feb. 2006.

8-port buffer management hardware

Performance Comparison

	NICT OPS Prototype	NICT's Top Data (As of Sep, 2006)	Electronic Router
IN/OUT ports	2	2 *	16
Bit rate	160 Gbps	160 Gbps	40 Gbps
Label processing	800 Mpps/port	10 Gpps (at 40Gbps)	125 Mpps/port **
Scheduling	4 Mpps	10 Gpps	2 Gpps **
Buffer	2/port	31/port	16000/port

* Can scale with nanosecond optical switches
** Estimated data: Assumption of wire rate processing of 40byte-packets

Conclusion

- We need high-throughput backbone network for ubiquitous society
- OPS will provide extremely high-throughput
  - Switching bandwidth is not limited
  - Buffer size is increasing
  - Electronic scheduling is fast
- NICT has developed OPS but,
  - Need more advanced devices (e.g., ns-switch) and systems

➢ *Thank you for your attention*

- Acknowledgment
  - N. Wada, H. Furukawa of Photonic Network Group in NICT for valuable discussion, collaboration, and some slides in OPS