Aggregation of MIMO Latency

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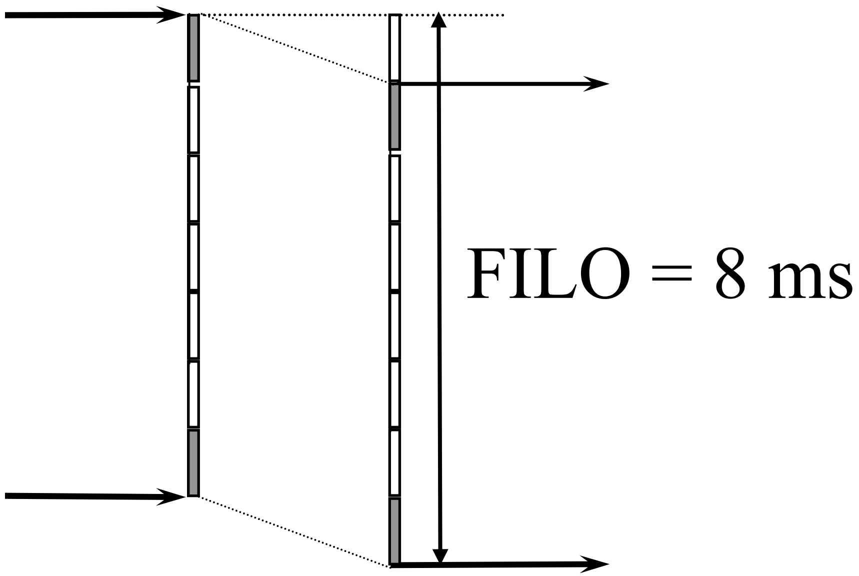
- Desired Properties of Metrics
- FILO, LILO Latency Issues
- MIMO Latency: Definition and Examples
- MIMO vs LILO
- Measurement Results
- MIMO Latency of a Path

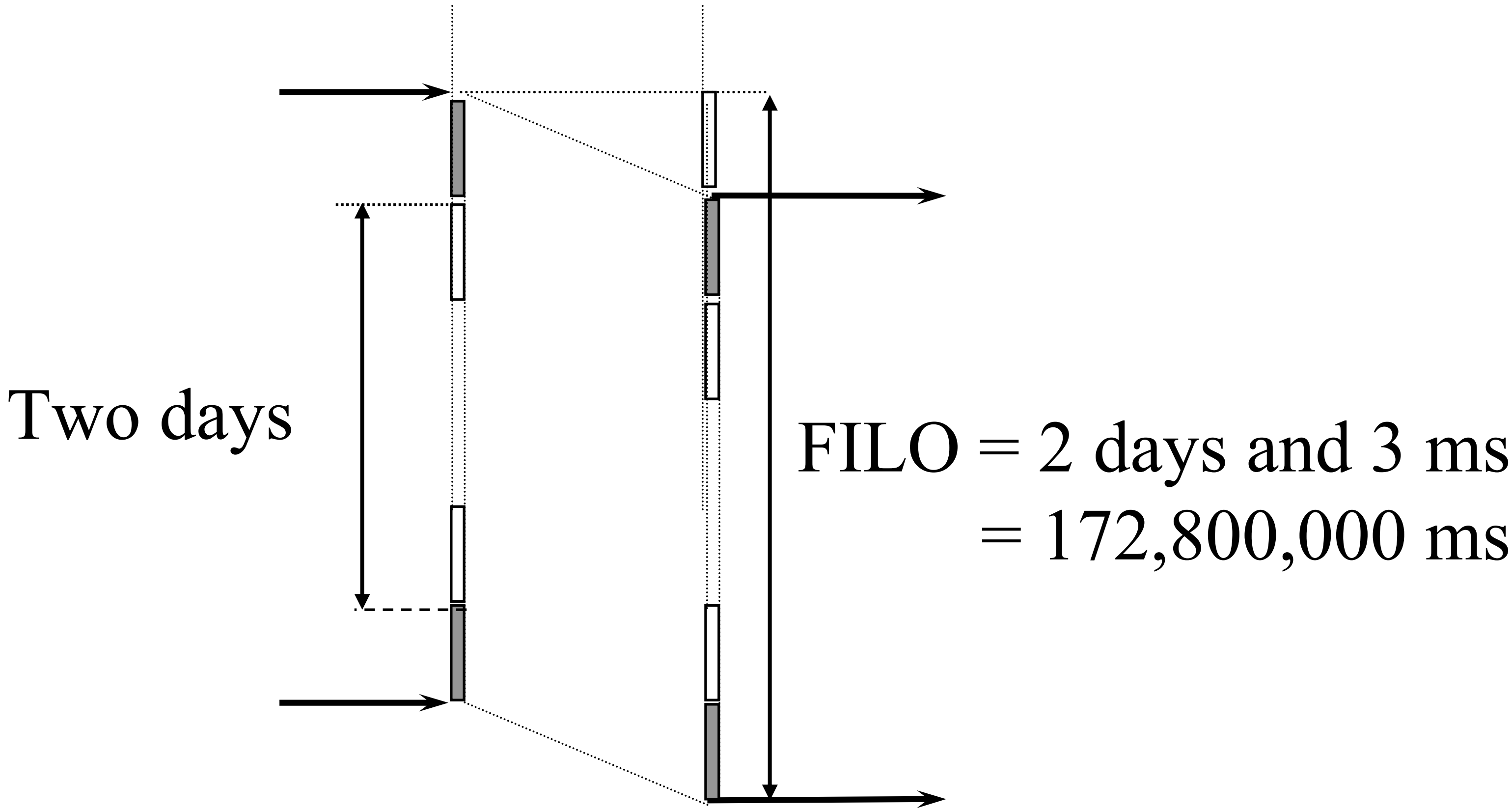
Desired Properties of Metrics

- Measured performance = Function{System, Workload}
- Metrics that depend highly on workload and less on the system are undesirable
- Example 2: Gap = 5 ms. Delay = 1 ms ⇒ FILO = 8ms



FILO Latency: Another Example

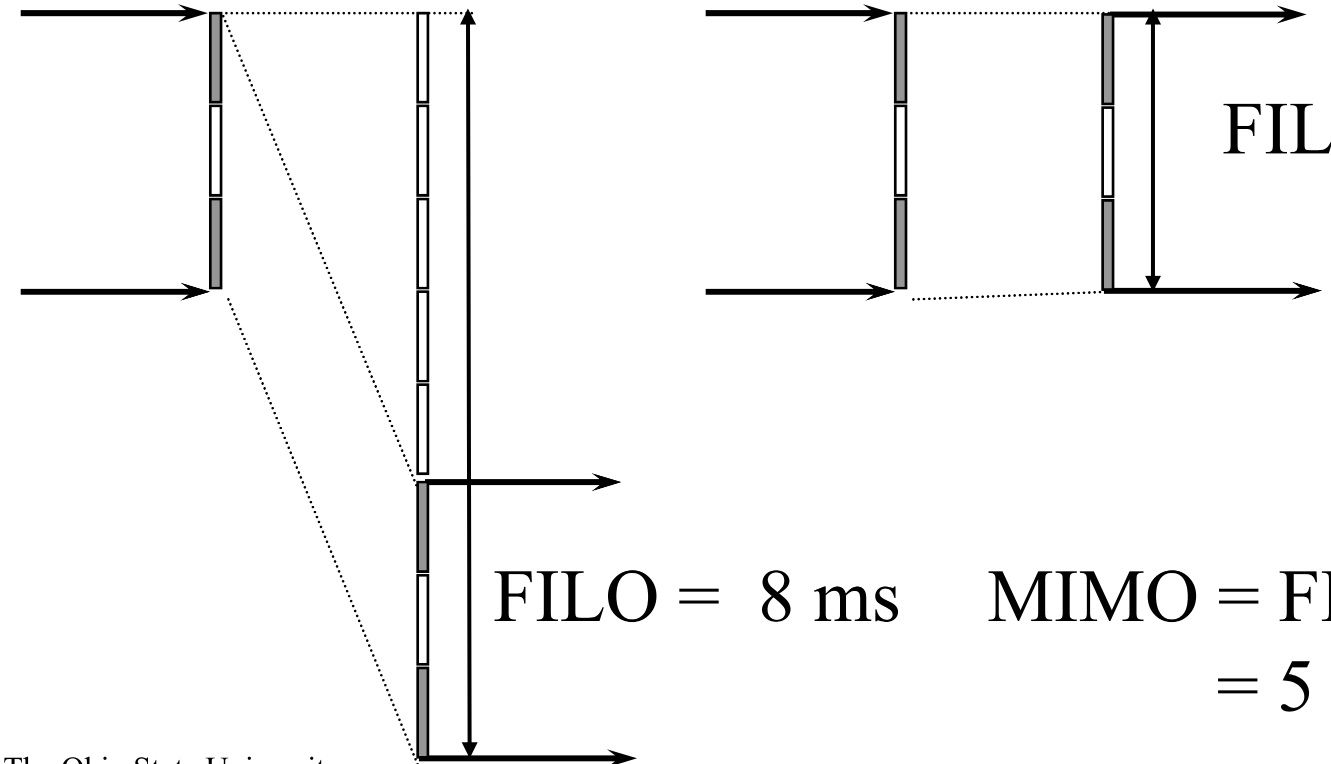
- Example 2: Gap = 2 days. Delay = 1 ms.
  $\Rightarrow$ FILO = 2 days + 3 ms



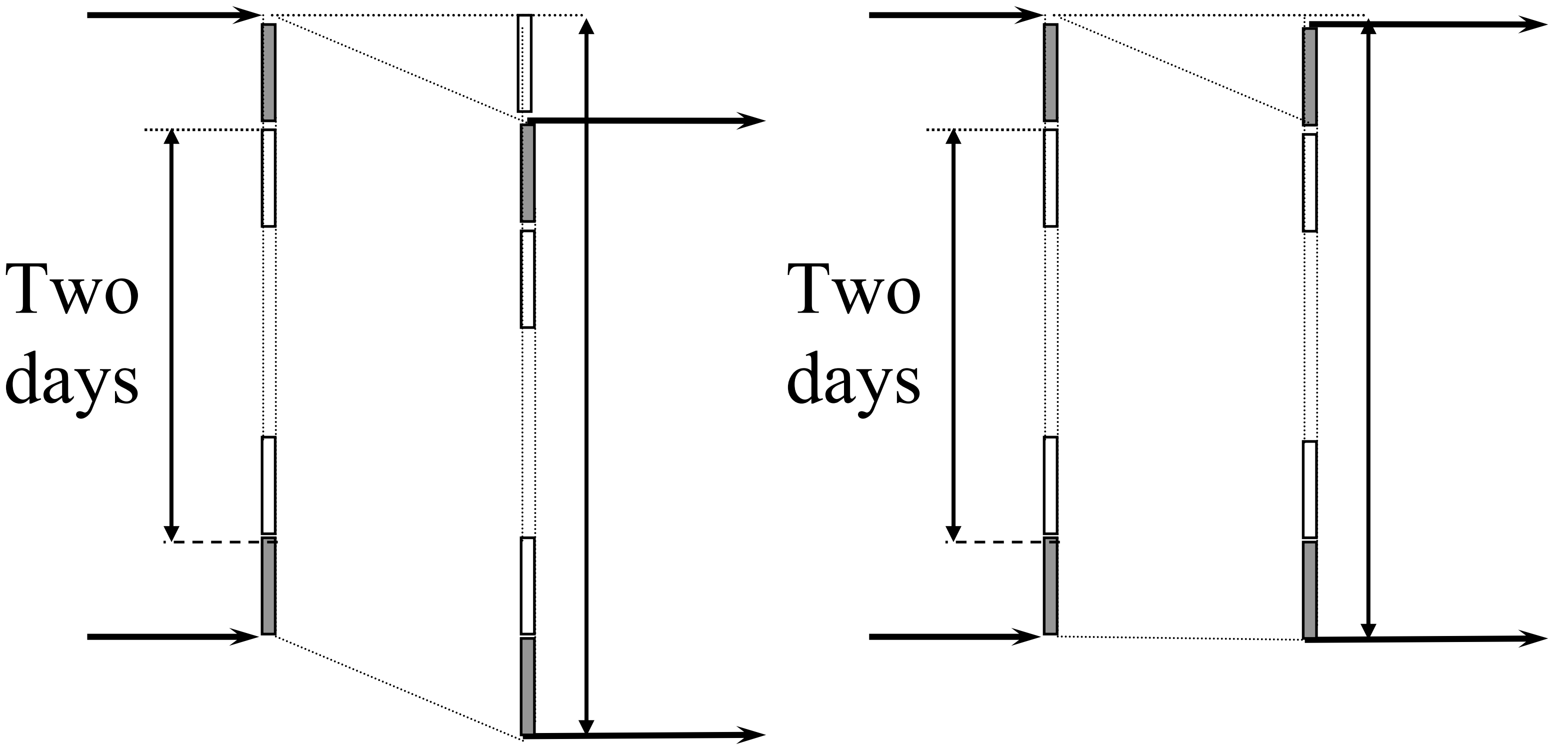
MIMO Latency: Definition

$$\text{MIMO Latency} = \text{FILO} - \text{FILO}_0$$

- FILO_0 = FILO latency through an ideal network
- Ideal Network = Zero length wire (in many cases)



MIMO Latency: Example 2



FILO = 2 days + 3 ms $\quad$ $FILO_0$ = 2 days + 2 ms

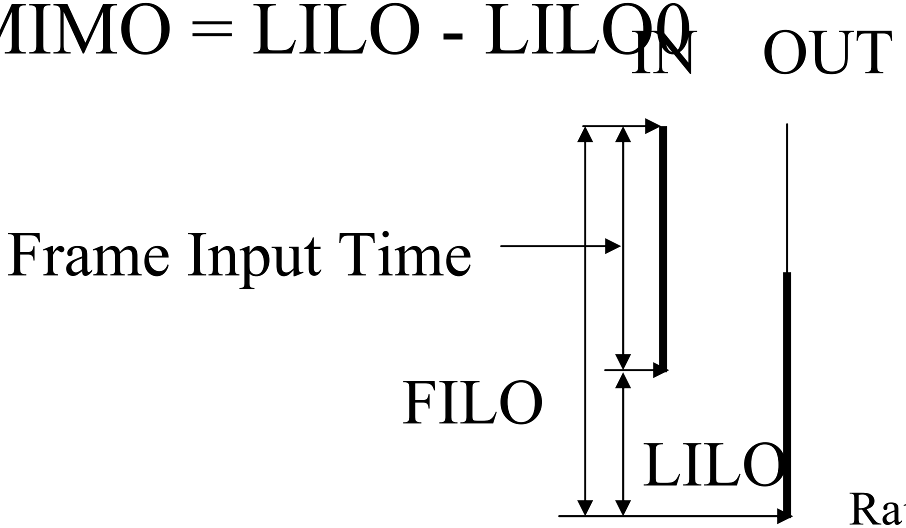
- MIMO Latency = FILO – $FILO_0$ = 1 ms

Another Equivalent Definition

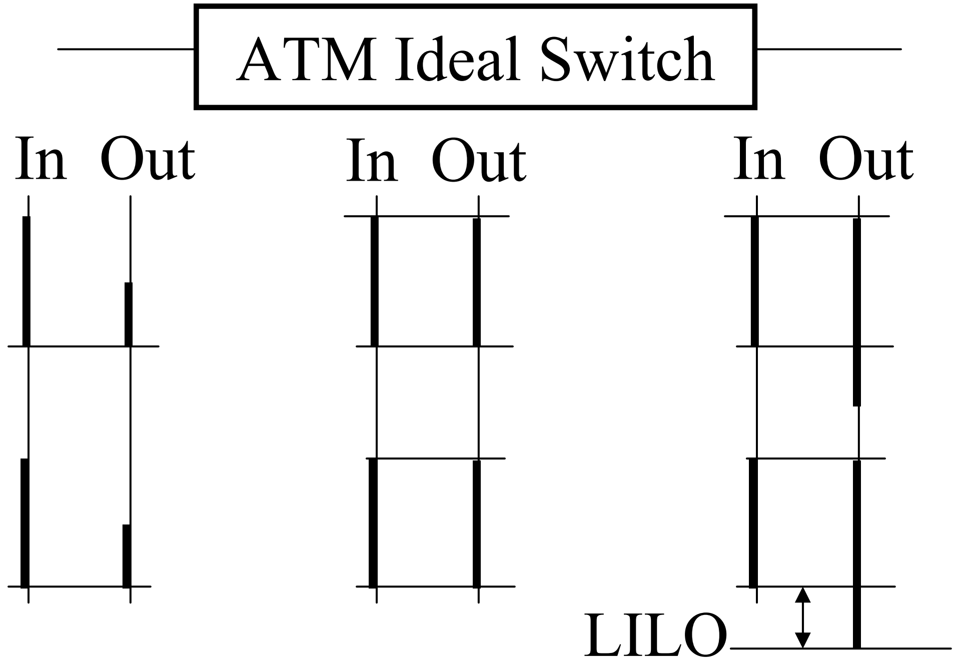
- First Definition: MIMO = FILO – $FILO_0$.

Index “0” indicates zero-delay switch

- Definition of FILO:
  - FILO = Frame Input Time + LILO
  - $FILO_0$ = Frame Input Time + $LILO_0$
- Second Definition: MIMO = LILO - LILO0

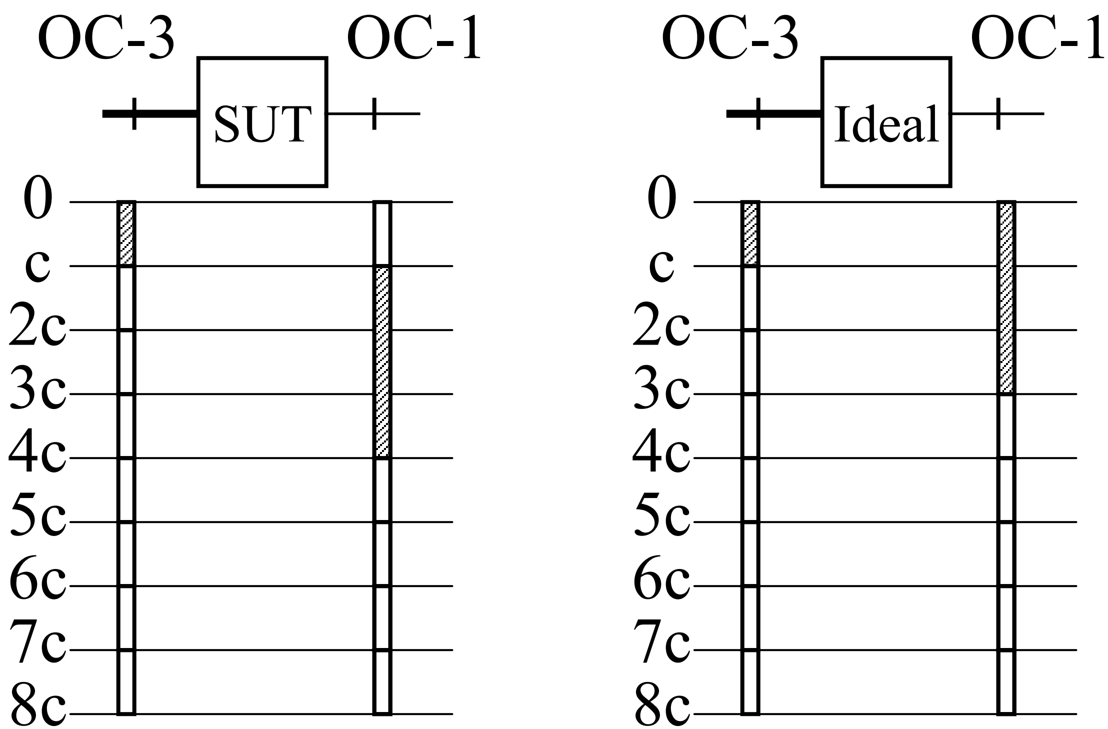


Delay Through an Ideal Switch



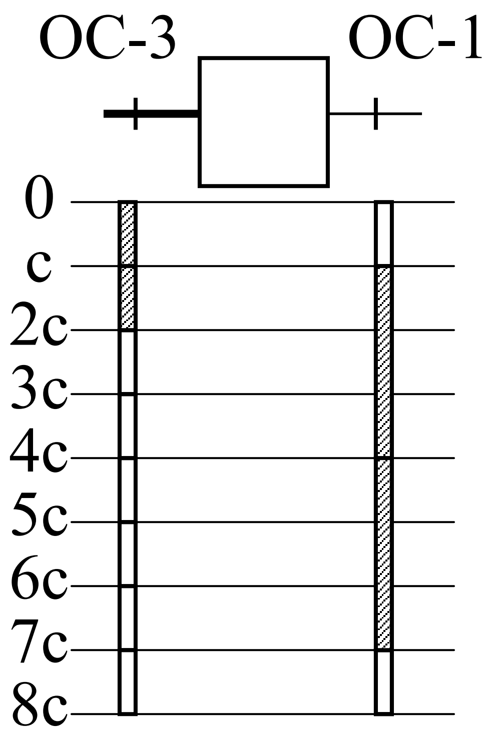
- $LILO_0 = 0$ if input speed $\leq$ output speed
- $LILO_0 > 0$ iff input speed > output speed

MIMO vs LILO: 1-Cell Frame



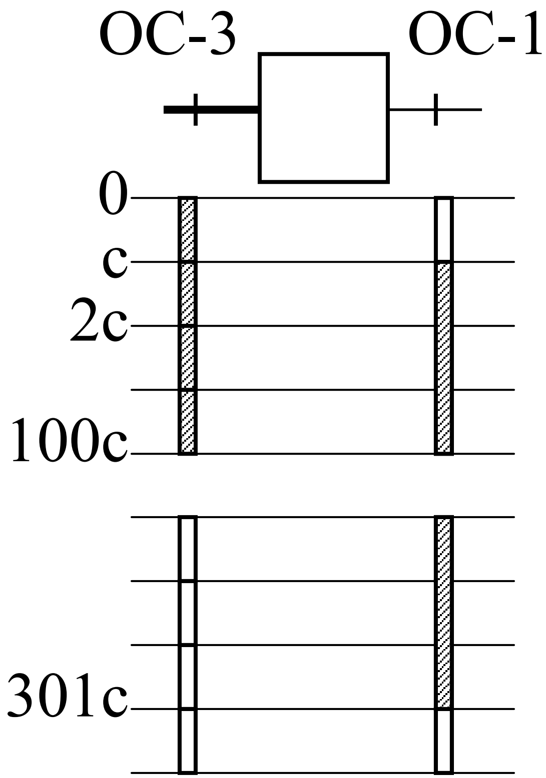
- Consider a switch with one cell delay
  - LILO = 3c, $LILO_0$ = 2c, MIMO = 1c

MIMO vs LILO: 2-Cell Frame



- Consider a switch with one cell delay
  - LILO = 5c, $LILO_0$ = 4c, MIMO = 1c

MIMO vs LILO: 100-Cell Frame



- Consider a switch with one cell delay
  - LILO = 301c, $LILO_0$ = 300c, MIMO = 1c

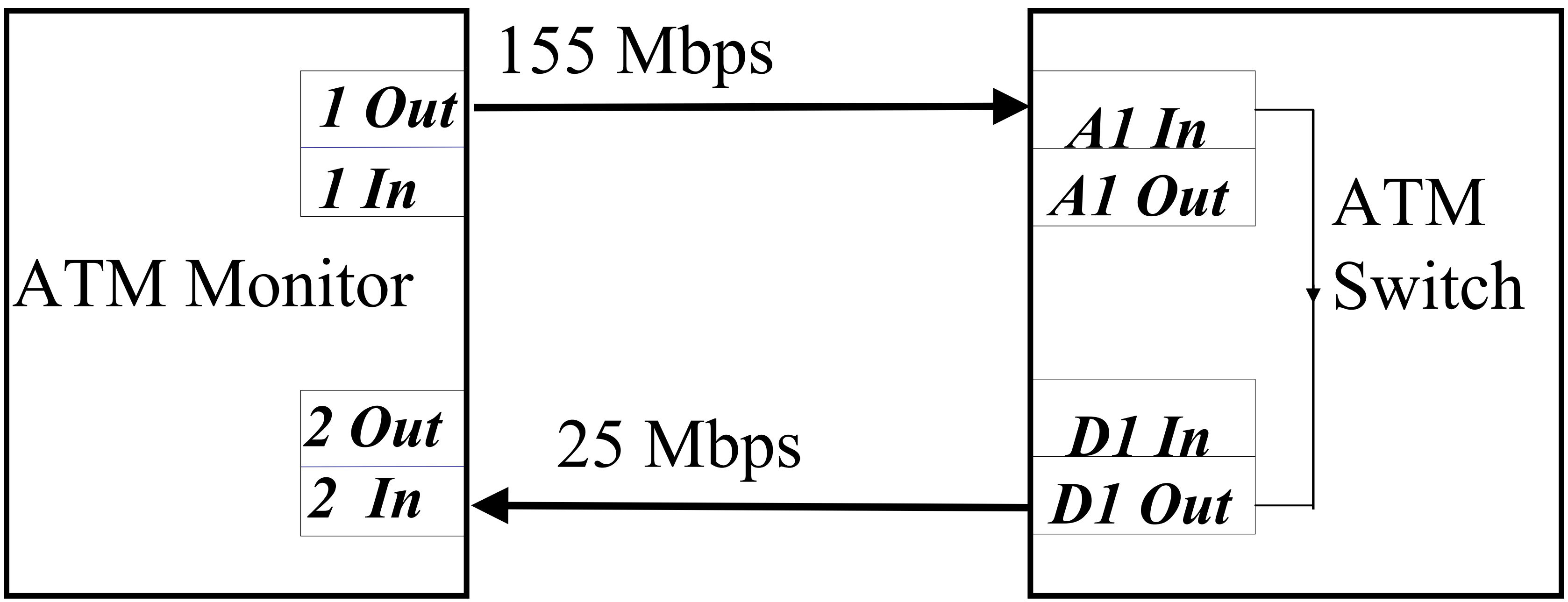
MIMO vs LILO

Frame Size	LILO	LILO0	MIMO
1c	4c	3c	1c
10c	31c	30c	1c
100c	301c	300c	1c
1,000c	3,001c	3,000c	1c
10,000c	30,001c	30,000c	1c
10,0000c	30,0001c	300,000c	1c

MIMO vs LILO

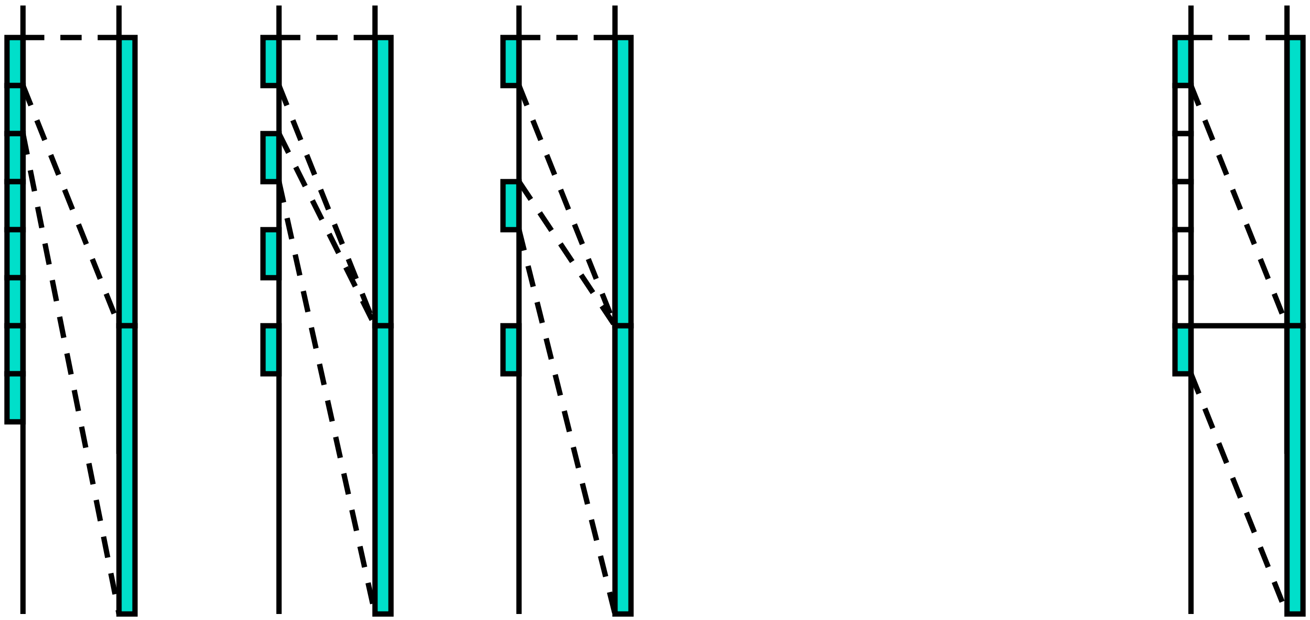
- MIMO = LILO - $LILO_0$
  - LILO measures the total delay.
  - $LILO_0$ measures the workload dependent part of the LILO delay. Depends upon the "mismatch" between input and output speed.
  - MIMO measures the delay introduced only by switch itself.
- For the n-cell Frame: n depends upon the workload
  - LILO = (3n+1)c, $LILO_0$ = 3nc, MIMO = 1c

Measurement Configuration



Workload

- Input Rate (155 Mbps) > Output Rate (25 Mbps)
- Gaps between the cells of the frame increased from 0 to 7 cells. Queueing up to 5-cell gap



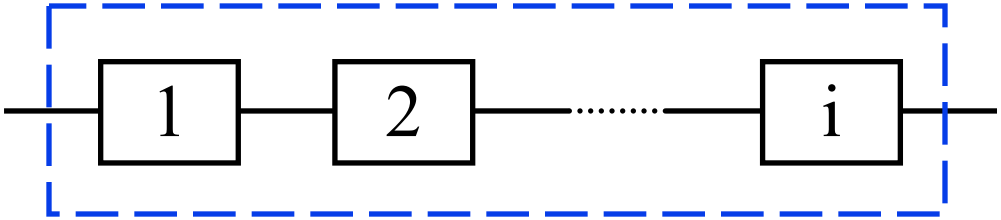
Measurement Results

- Input 155Mbs, Output 25Mbs, 32-cell frame
- LILO and FILO depend heavily from frame pattern
- MIMO indicates the switch contribution in the delay

Test No.	Frame Pattern	$LILO_0$	LILO	FILO	MIMO
1	No gap	351.71	385.01	563.3	33.3
2	1-cell gaps	263.98	295.78	561.8	31.8
3	2-cell gaps	176.25	209.05	562.8	32.8
4	3-cell gaps	88.52	119.82	561.3	31.3

All times are in microseconds

MIMO Latency of a Path



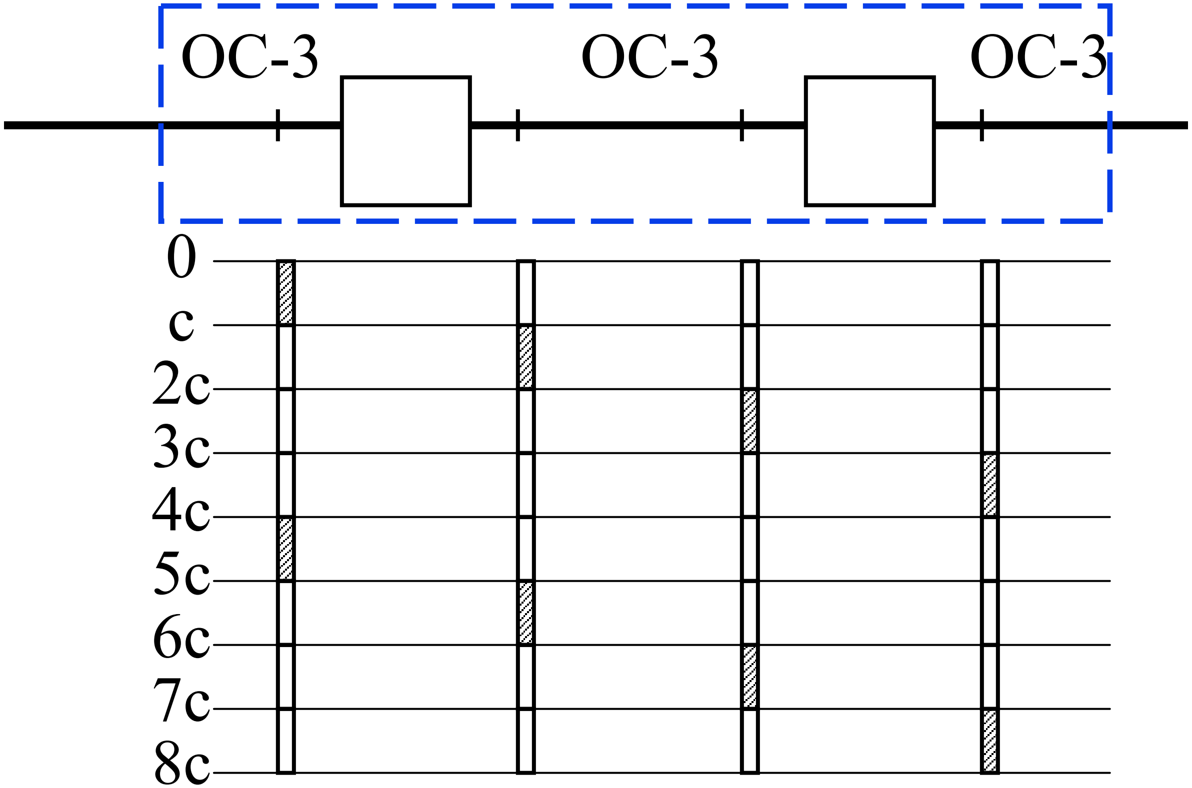
- For each switch or wire:
  - $MIMO_i = LILO_i - LILO_{0i}$
- Similarly for the network path:
  - $MIMO_\Sigma = LILO_\Sigma - LILO_{0\Sigma}$
- Since: $LILO_\Sigma = \Sigma\, LILO_i$
  - $MIMO_\Sigma = \Sigma\, MIMO_i + \Sigma\, LILO_{0i} - LILO_{0\Sigma}$

Delay Components in a path

$$MIMO_{\Sigma} = \Sigma\ MIMO_i + \Sigma\ LILO_{0i} - LILO_{0\Sigma}$$

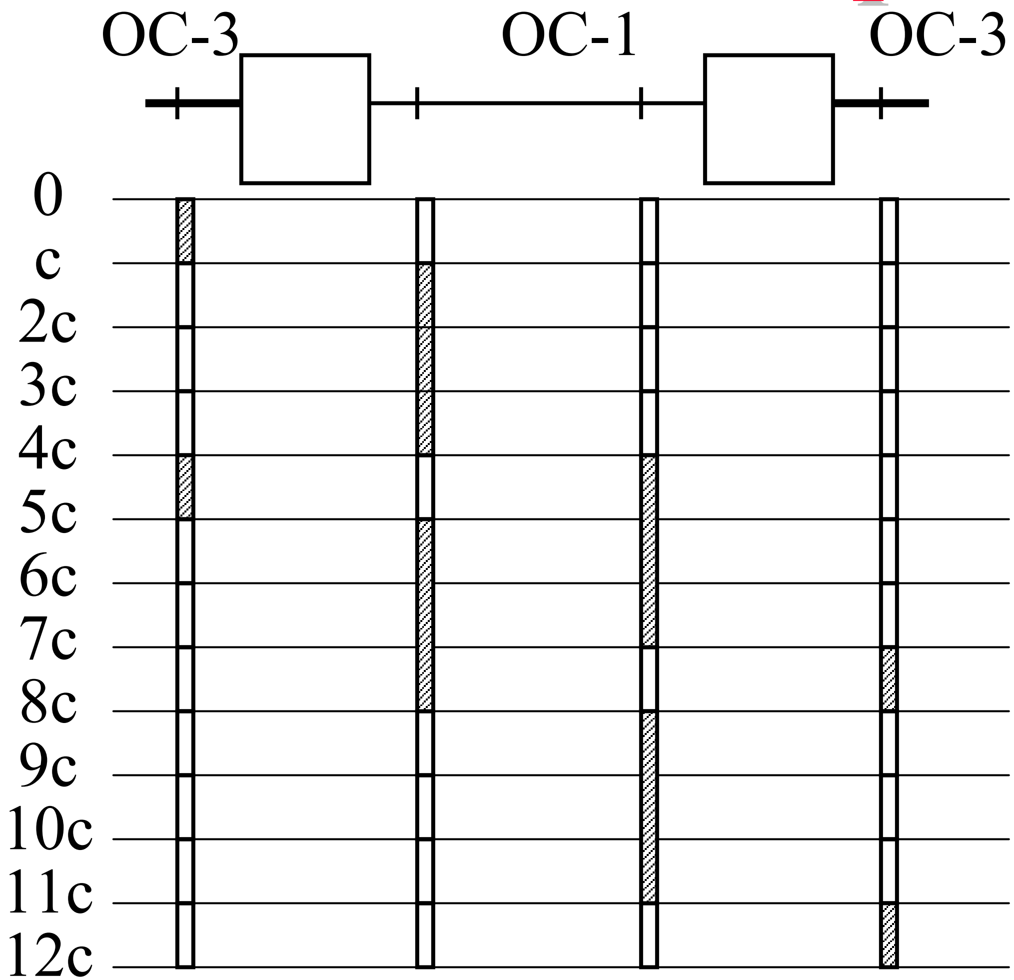
- $MIMO_i$ component delay introduced by switch *i*
- $LILO_{0i}$ workload-dependent component delay introduced the mismatch of the input-output speeds of the ith component. $LILO_{0i}$ can be computed from Input/output speed of the ith component
- $LILO_{0\Sigma}$ workload-dependent delay that would have been introduced if the path were to be replaced by an ideal switch. $LILO_{0\Sigma}$ can be computed from the input/output speed of the entire path.

Example 1



- For each component: Input = Output $\Rightarrow$ $LILO_{0i} = 0$
- For the path: Input = Output $\Rightarrow$ $LILO_{0\Sigma} = 0$
- $MIMO_{\Sigma} = \Sigma MIMO_i + \Sigma\ LILO_{0i} - LILO_{0\Sigma} = c + c + c = 3c$

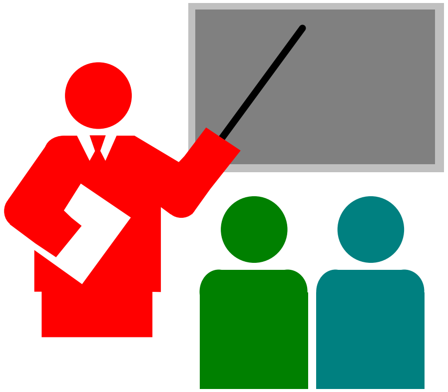
Example 2



- Middle link OC-1
  - $MIMO_1 = c$
  - $MIMO_2 = 3c$
  - $MIMO_3 = c$
- $LILO_{01} = 2c$
- $LILO_{02} = 0$
- $LILO_{03} = 0$
- $LILO_{0\Sigma} = 0$

$$MIMO_\Sigma = \Sigma\, MIMO_i + \Sigma\, LILO_{0i} - LILO_{0\Sigma}$$
$$= (c+3c+c) + (2c+0+0) - 0 = 7c$$

Summary



- FILO and LILO are significantly affected by the workload
- FILO is meaningless if large gaps in the frames
- LILO is meaningless if large number of back-to-back frames
- MIMO provides system latency.
- MIMO can be aggregated.