Frame Delay Through ATM Networks: MIMO Latency

Gojko Babic, Raj Jain, Arjan Durresi

Raj Jain is now at
Washington University in Saint Louis
Jain@cse.wustl.edu
http://www.cse.wustl.edu/~jain/

- Why frame level?
- Measuring frame delay inside the network
- Problems with traditional definitions
- MIMO latency
- Measurement experiences with MIMO latency

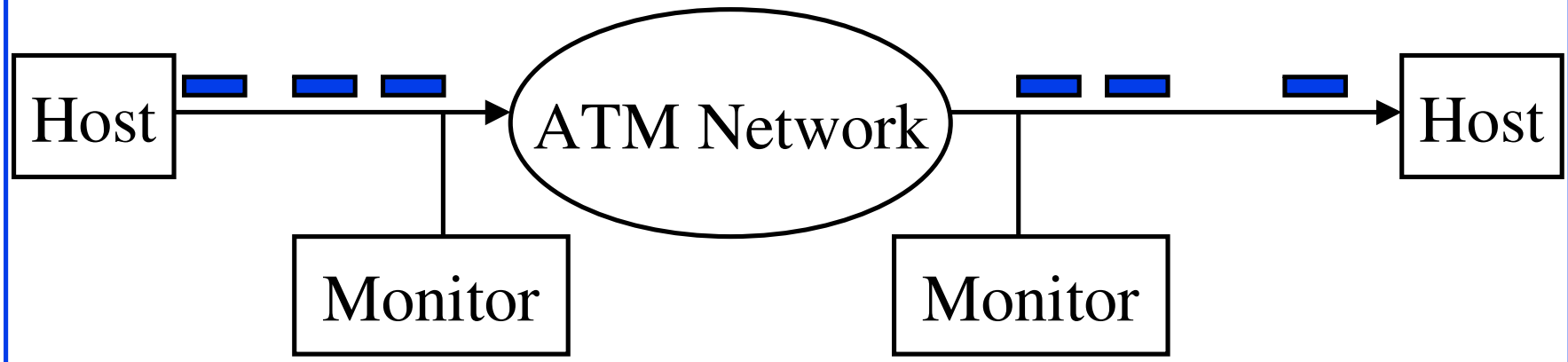
References: ATM forum contributions on MIMO latency are at: http://www.cis.ohio-state.edu/~jain/

Why Frame Level?

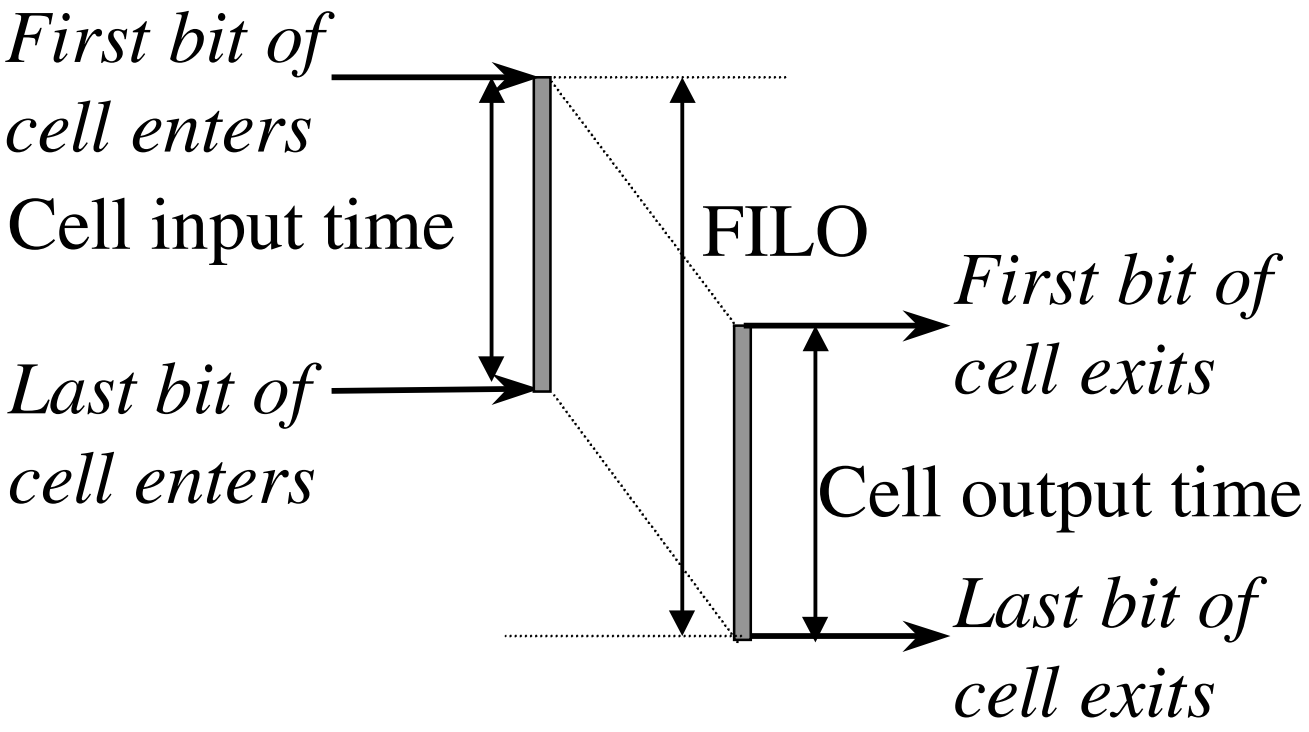
- Performance seen by the user ≠ Cell level QoS
  For example,
  CLR = 0.1% may mean a frame loss rate of 0.1% in one switch or 0.001% in another.
- Data applications care for frame loss rate and frame delay and not CLR, CTD.
- Video applications care for
  - Frame loss rate
  - Frame delay variation
  - Frame transfer delay

Problem Statement

- Frame level performance of ATM Networks
- Frame = AAL5 PDU
- Network = Switch or combination of switches
- Measurements probe outside the host

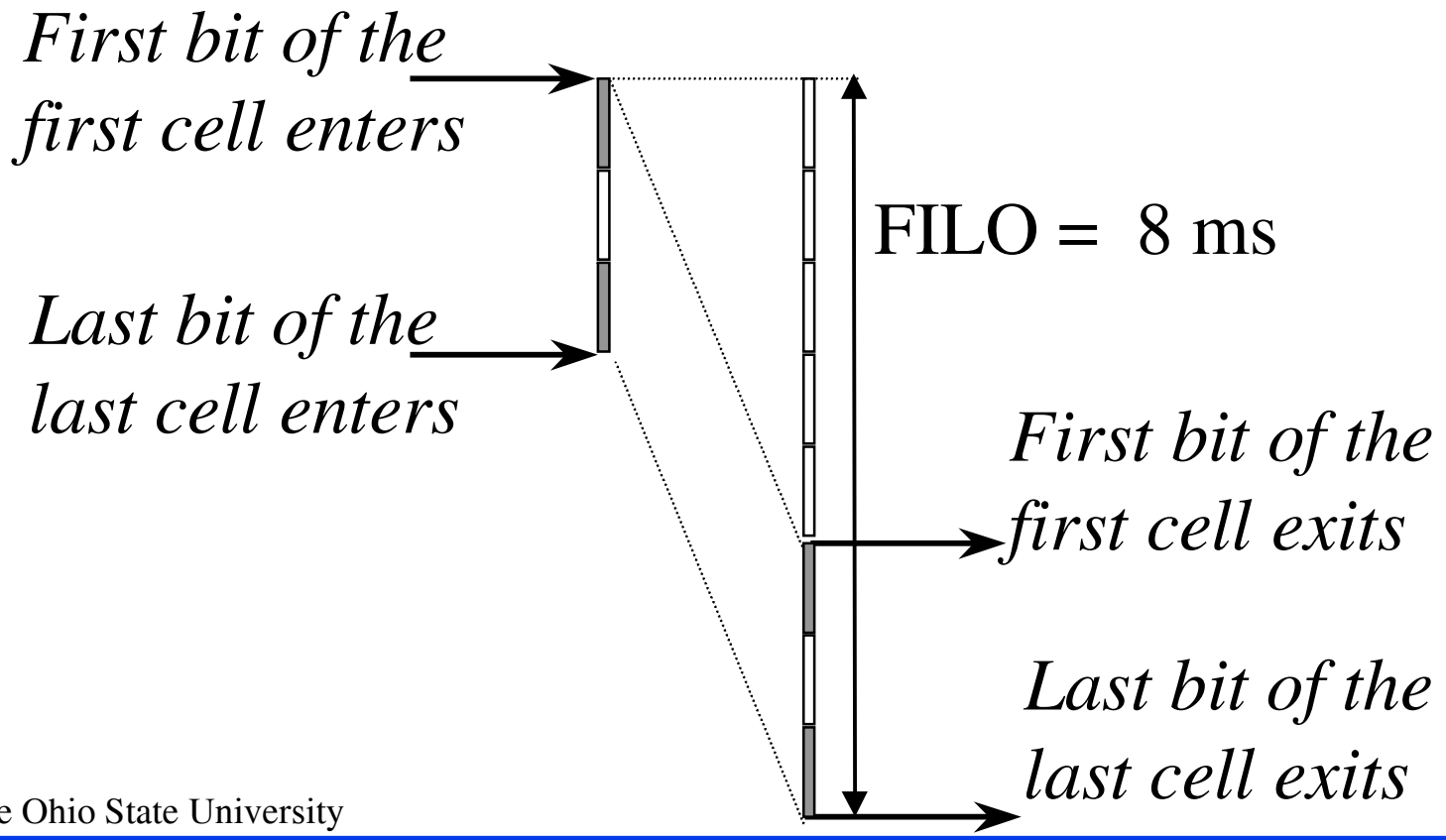


FILO Latency at Cell Level



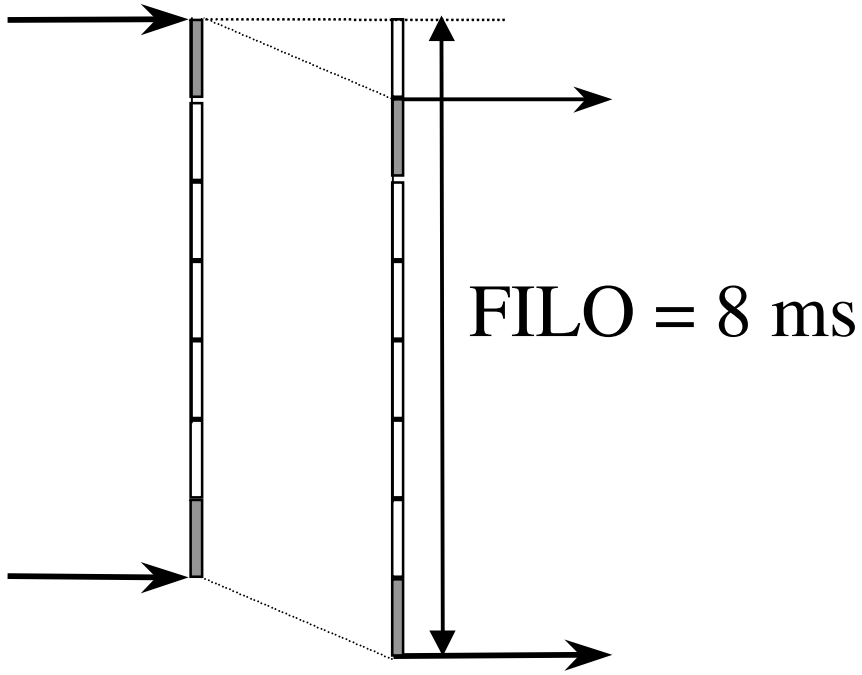
FILO Latency at Frame Level

- Example 1: Two-cell frame. Cell time =1 ms. Gap = 1 ms. Network delays each cell by 5 ms.
  $\Rightarrow$ FILO = 8 ms



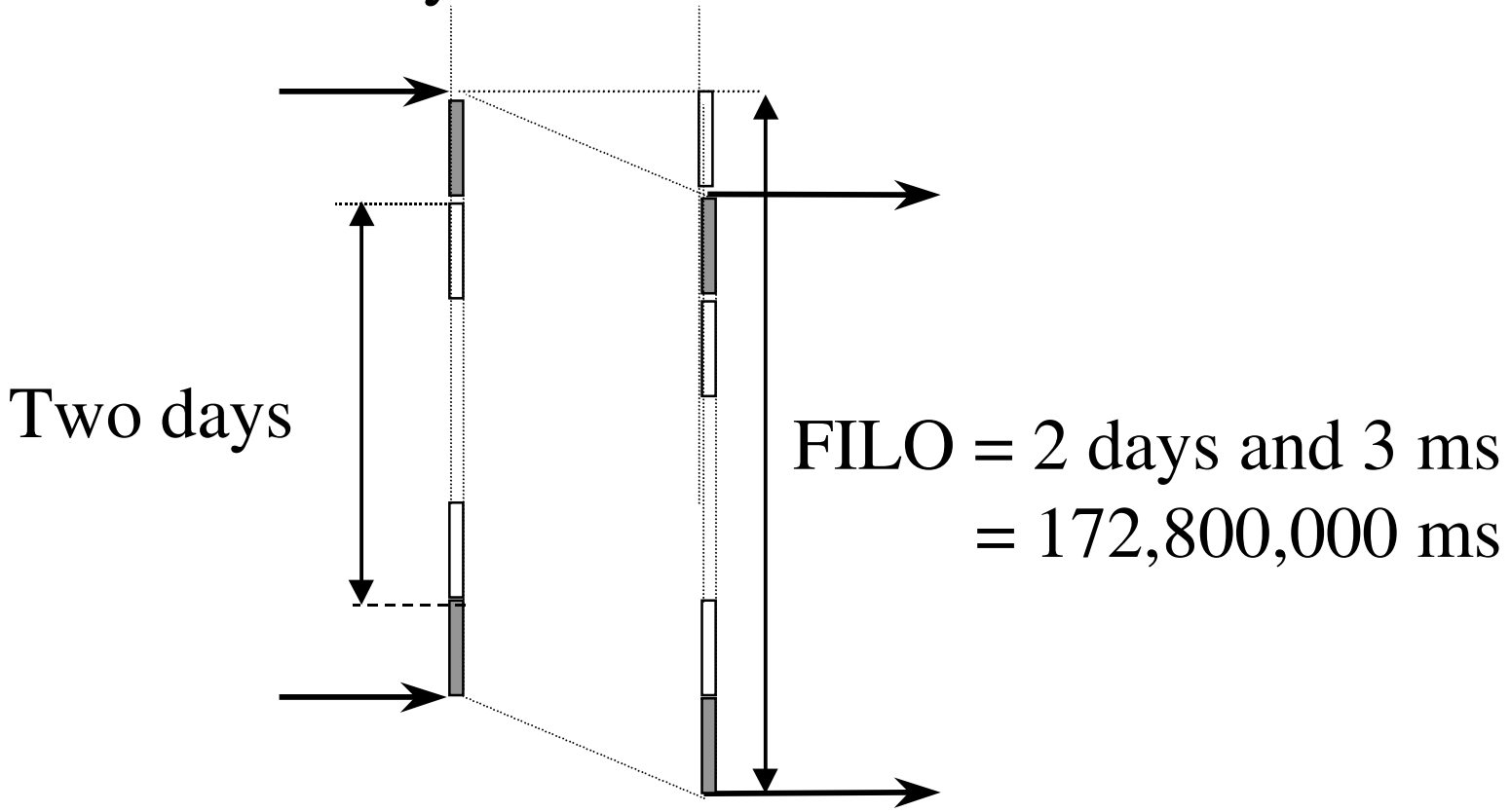
Desired Properties of Metrics

- 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 = 8 ms



FILO Latency: Another Example

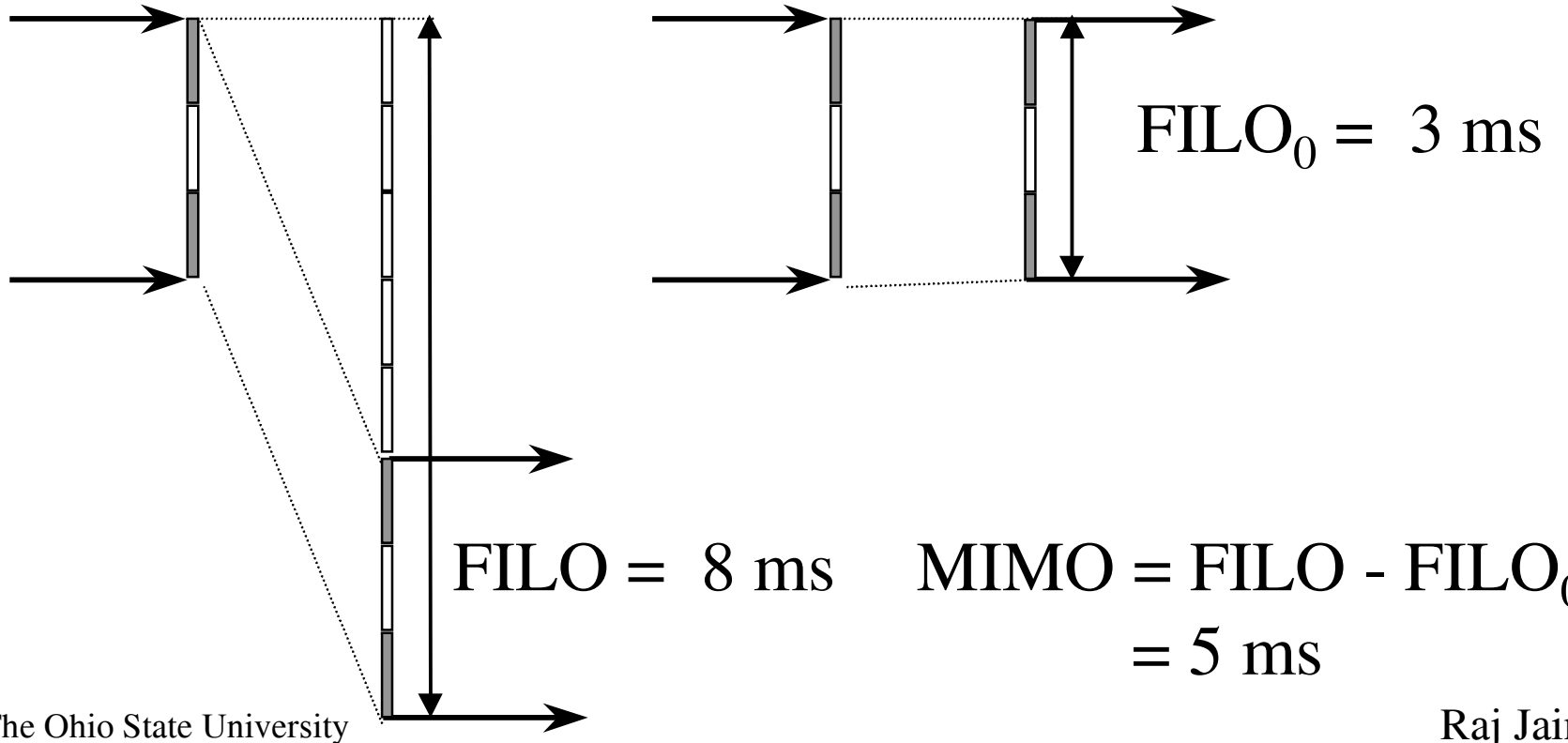
- Example 3: Gap = 2 days. Delay = 1 ms.
  $\Rightarrow$ FILO = 2 days + 3 ms



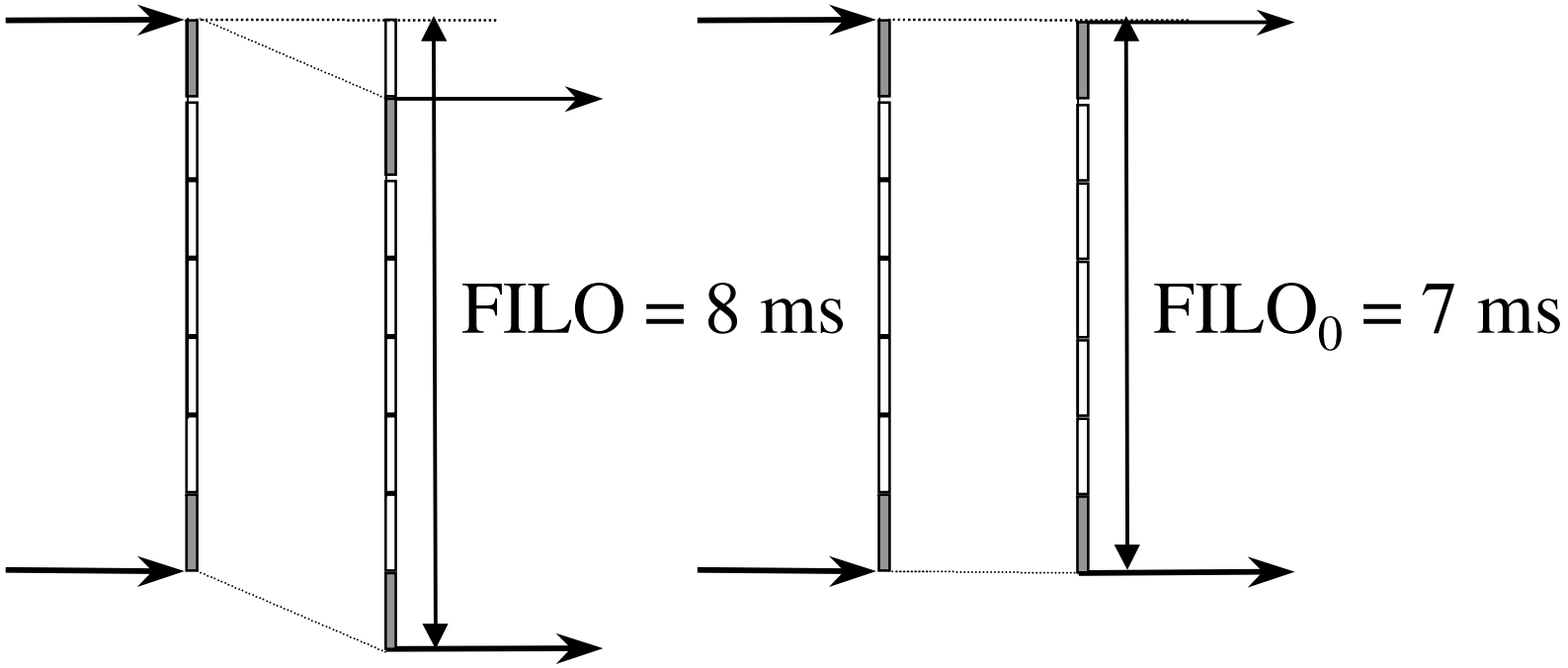
MIMO Latency: Definition

MIMO Latency = FILO – $FILO_0$

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

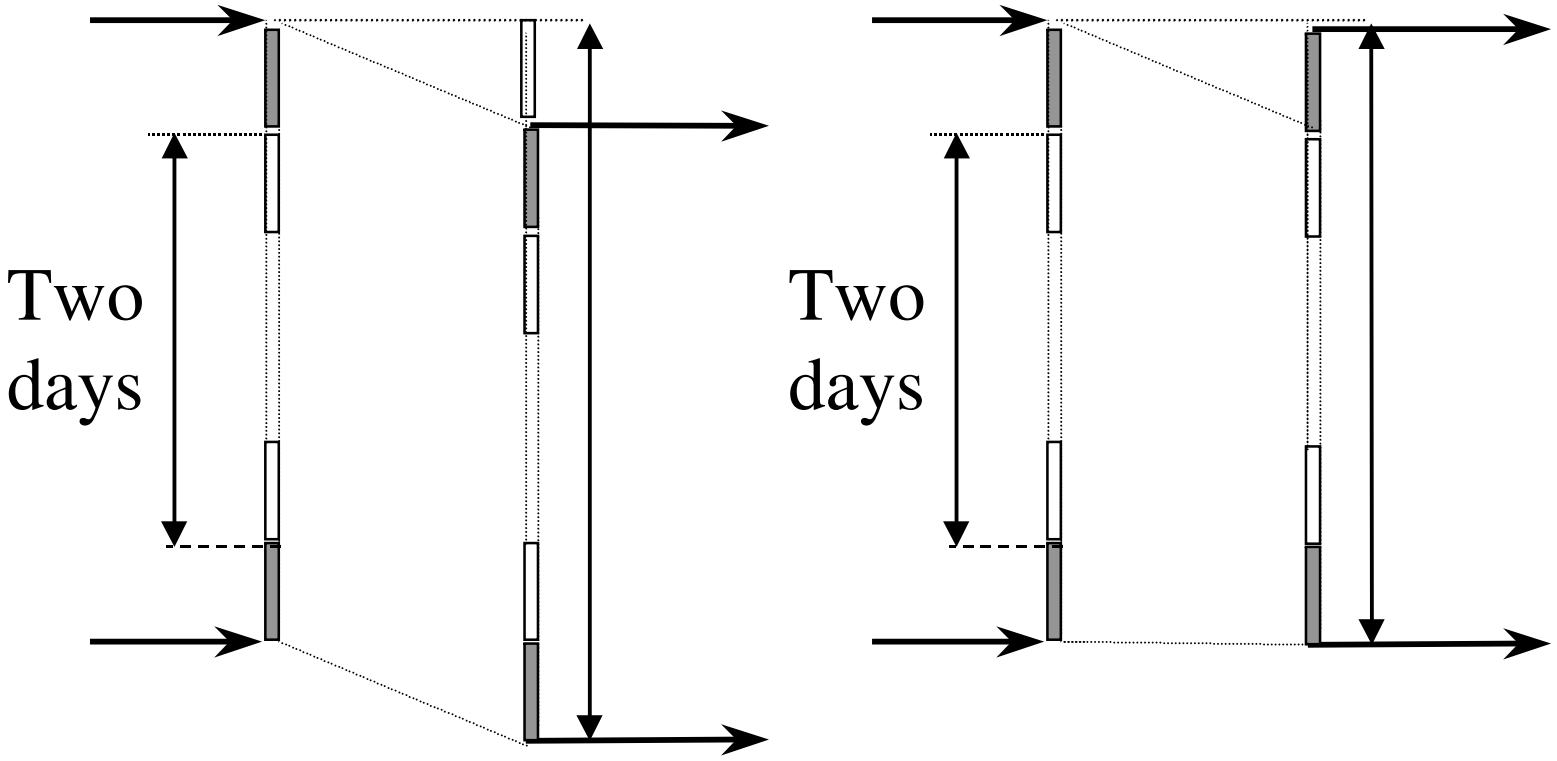


MIMO Latency: Example 2



- MIMO = FILO - $FILO_0$ = 1 ms

MIMO Latency: Example 3

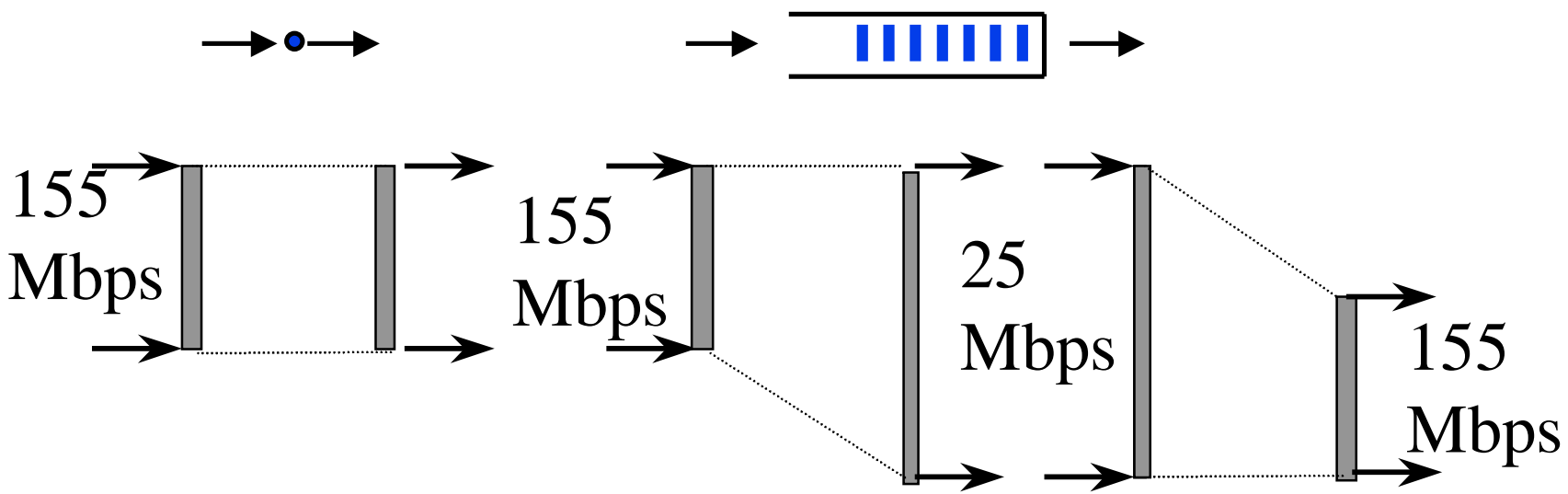


FILO = 2 days + 3 ms

$FILO_0$ = 2 days + 2 ms

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

Ideal Network: Cell Delay



(a) (b) (c)

Input Rate = Output Rate

Input Rate > Output Rate

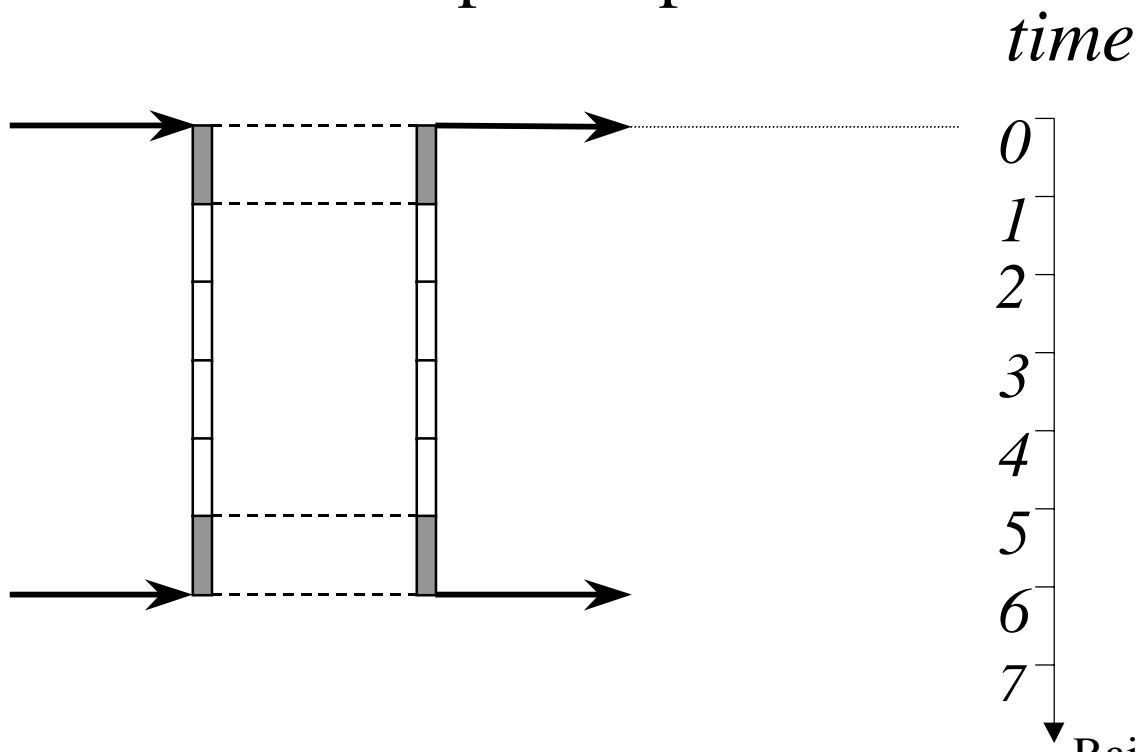
Input Rate < Output Rate

- $FILO_0$ = Max{Cell Input Time, Cell Output Time}

Ideal Network: Frame Delay

Case 1: Input Rate = Output Rate

- $FILO_0$ = Frame Input Time = FILI
  = Σ Cell Input Times + Σ Input Gaps



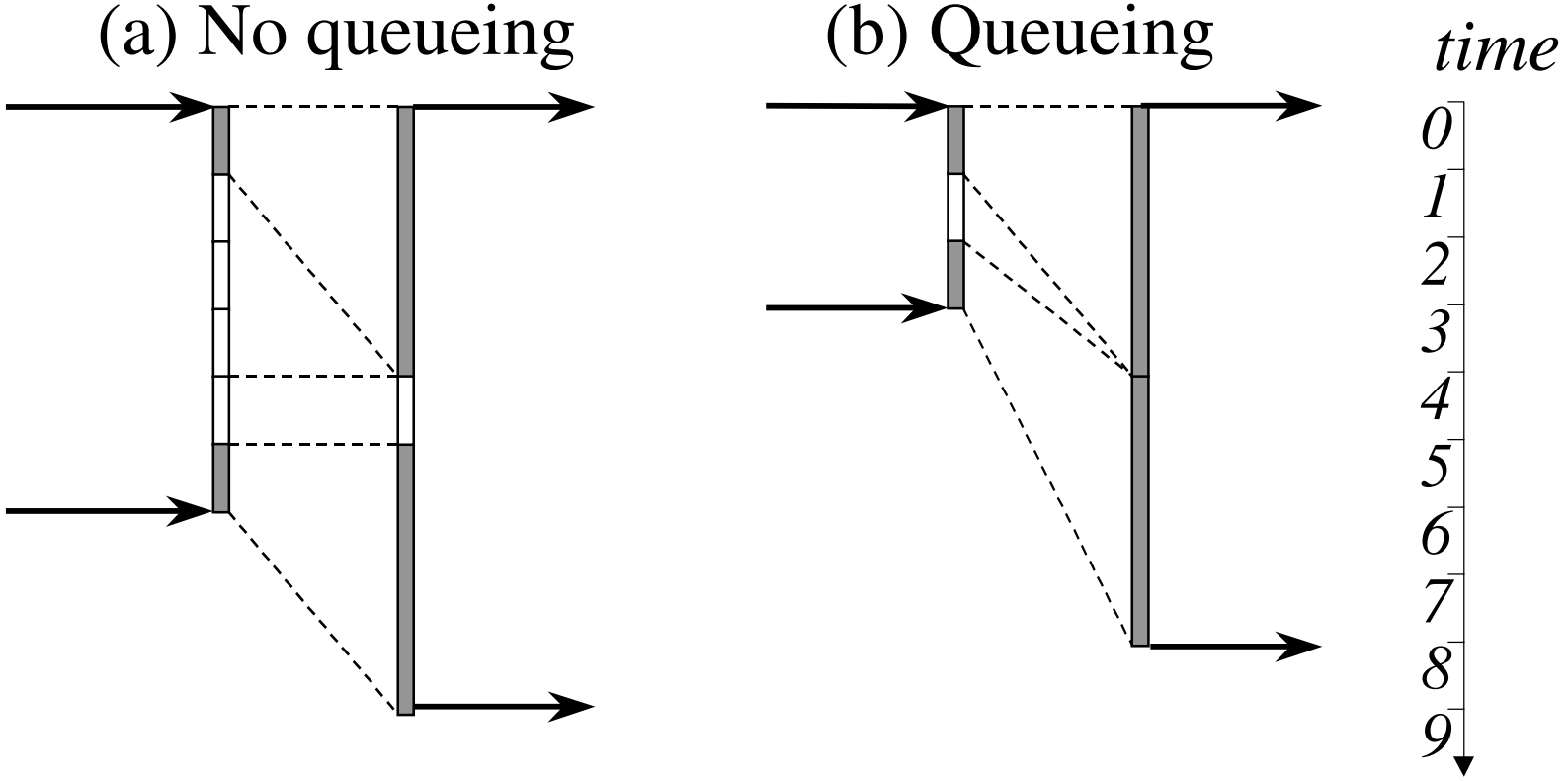
Ideal Network (Cont)

Case 2: Input Rate > Output Rate

Two examples:

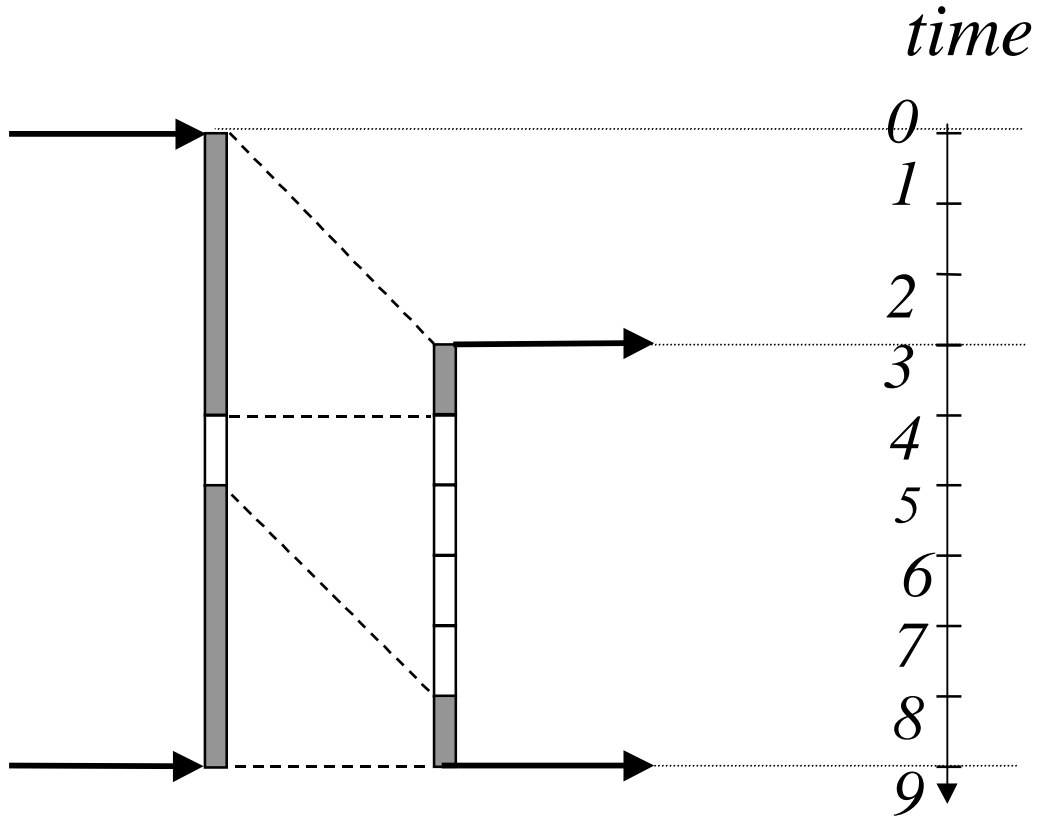
(a) No queueing

(b) Queueing



Ideal Network (Cont)

- Case 3: Input Rate < Output Rate



General Method for $FILO_0$

t = time since the first bit in

Begin with $FILO_0 = 0$

For each cell:

$FILO_0 = \max\{t, FILO_0\} + \text{Max}\{CIT, COT\}$

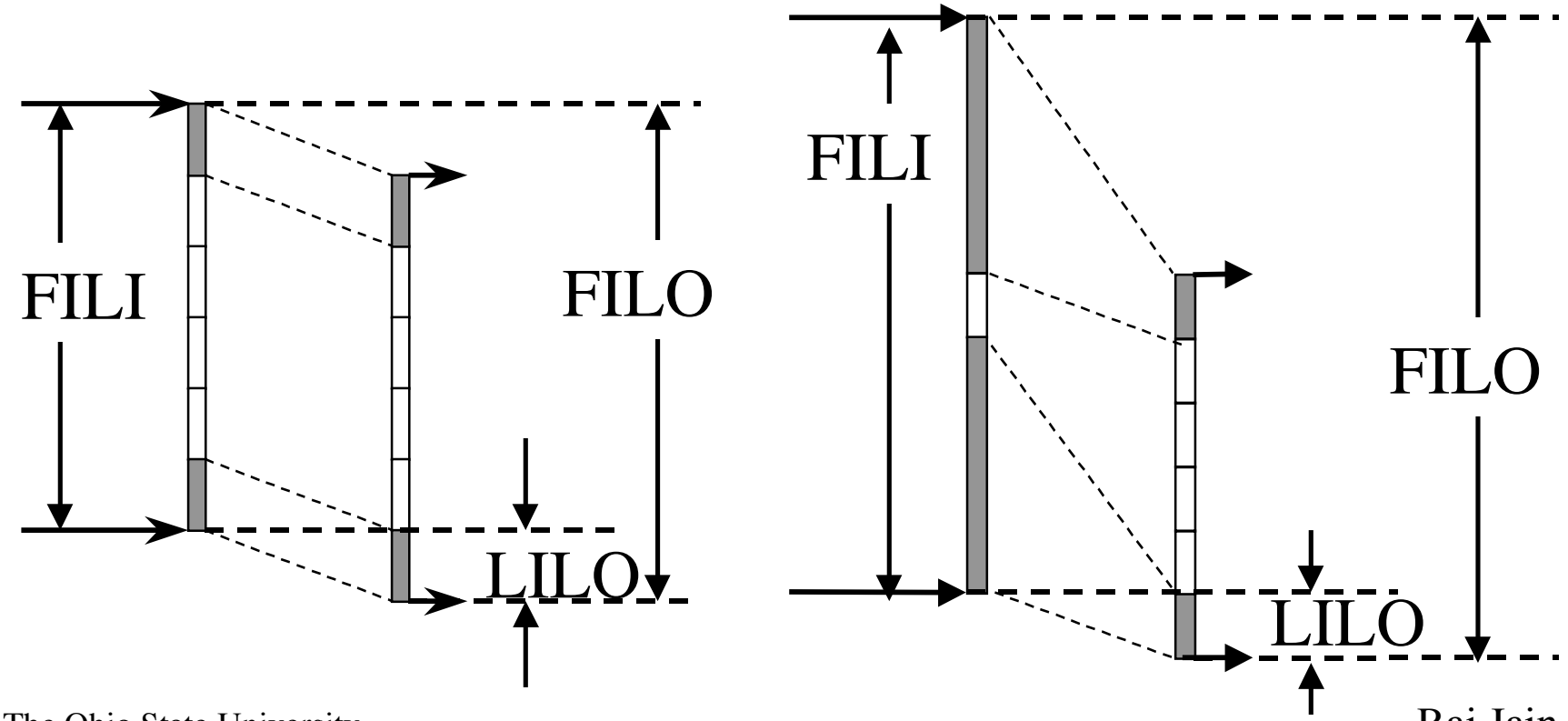
Where:

CIT = Cell input time = 424 bits/input rate in bps

COT = Cell output time = 424 bits/output rate in bps

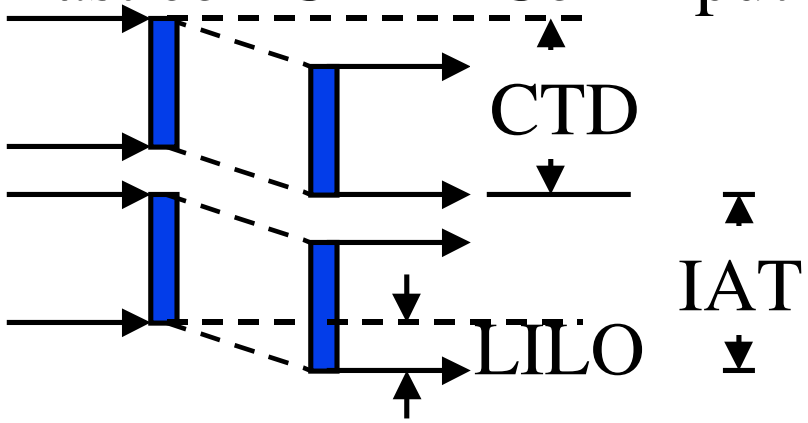
Special Cases

- Input Rate ≤ Output Rate
- FILO0 = Frame Input Time = FILI
  MIMO = FILO - FILI = LILO

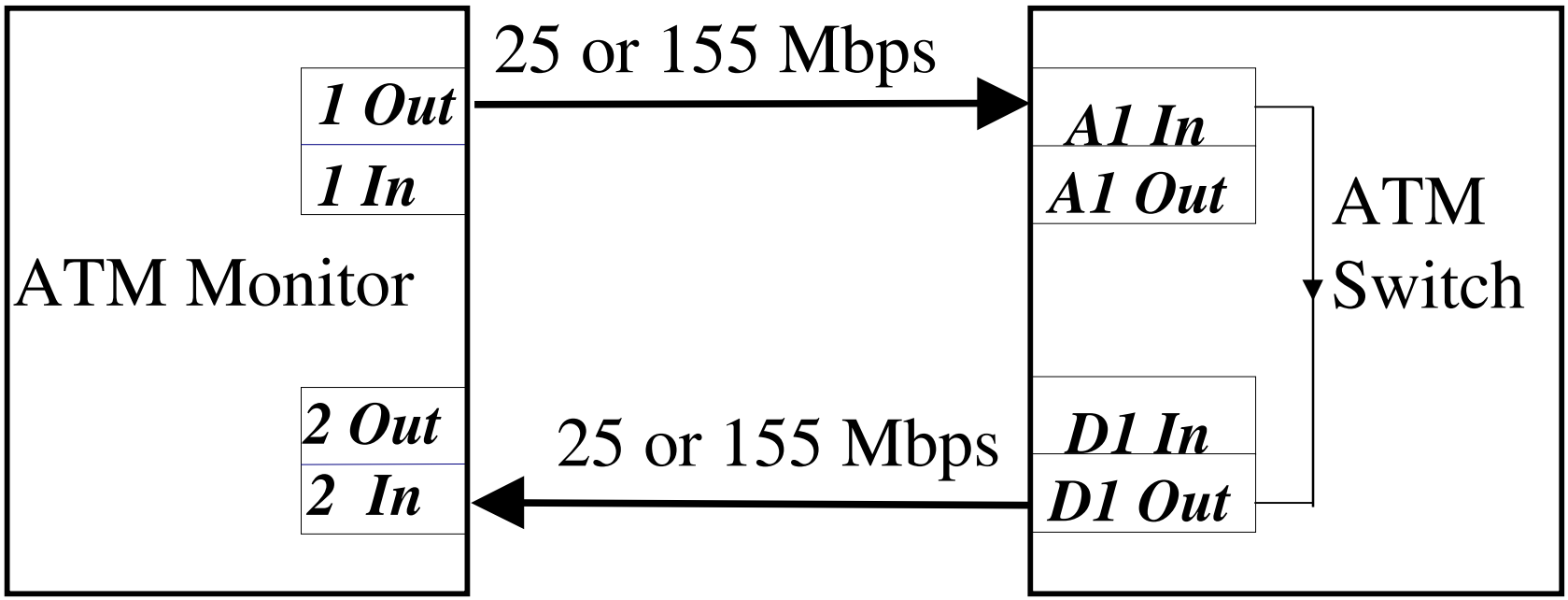


Measurement Experiences

- CTD = Cell Transfer Delay = Cell FILO latency
- IAT = Inter-arrival time between any two cells
  = Last-bit in of 1st to last bit in of 2nd
- Most monitors have a stated resolution, e.g. 0.5 ms
- Frame FILO = 1st cell CTD
  + 1st cell to last cell IAT at the output
- Frame LILO = Last cell CTD - Cell input time



Measurement Configuration



Measured Results 1

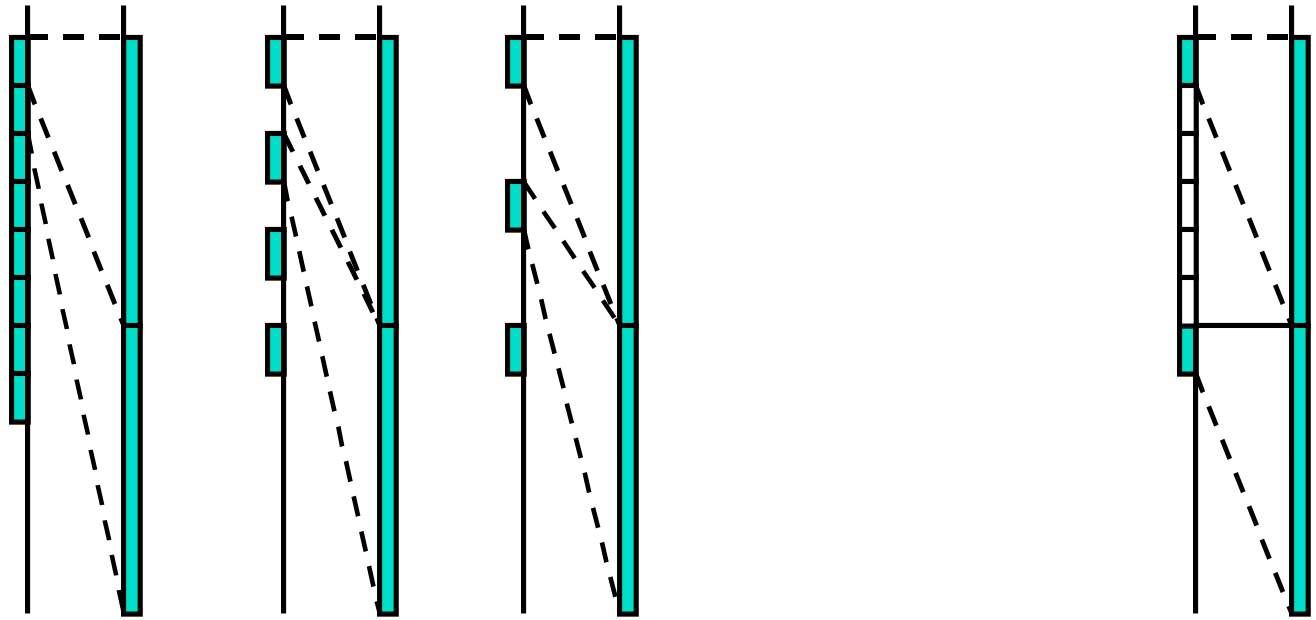
- Input Rate = Output Rate = 155 Mbps
- All times are in μs

1st Cell CTD	1st Cell to Last Cell Inter-Arrival Time	MIMO Latency (2)	FILO Latency (3)	MIMO Latency (1)
21.5	541.0	18.67	562.5	18.91
18.5	543.5	18.17	562.0	18.41

- Conclusion: Both methods of MIMO calculation are within the monitor tolerance

Measured Results 2

- 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



Measured Results 2 (Cont)

Gap	1st Cell CTD	1st Cell to Last Cell Inter-arrival Time	FILO0	FILO Latency (3)	MIMO Latency (1)
0	36.8	526.5	530.0	563.3	33.3
1-cell	35.8	526.0	530.0	561.8	31.8
2-cell	36.8	526.0	530.0	562.8	32.8
3-cell	34.8	526.5	530.0	561.3	31.3
4-cell	40.8	519.5	530.0	560.3	30.3
5-cell	36.8	526.5	542.9	562.8	19.9
6-cell	36.8	616.0	630.6	652.8	22.2
7-cell	35.3	705.0	718.4	740.3	21.9

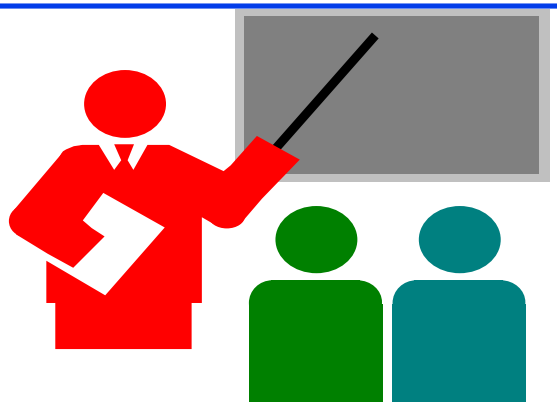
- FILO increases with increasing gap.
  MIMO is unaffected by gap. Does reflect queueing.

Measured Results 3

- Input Rate (25 Mbps) < Output Rate (155 Mbps)
- Two tests with random gaps between cells

Last Cell CTD	MIMO Latency (2)	1st Cell CTD	1st Cell to Last Cell Inter-arrival Time	$FILO_0$	FILO Latency	MIMO Latency (1)
32.0	15.44	31.0	535.0	550.0	566.0	16.0
32.5	15.94	33.0	1067.5	1082.6	1100.5	17.9

- Conclusion: FILO is affected by gaps. MIMO is unaffected.



Summary

- Users care about frame level performance of ATM networks
- Unlike other networking technologies, frames in ATM are not continuous
- Traditional frame delay metrics are affected by gaps
- MIMO latency has been designed to reflect network behavior
- MIMO can be measured with current monitors

Thank You!