

# 99-0368

# On LCD and MIMO

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These slides are available at

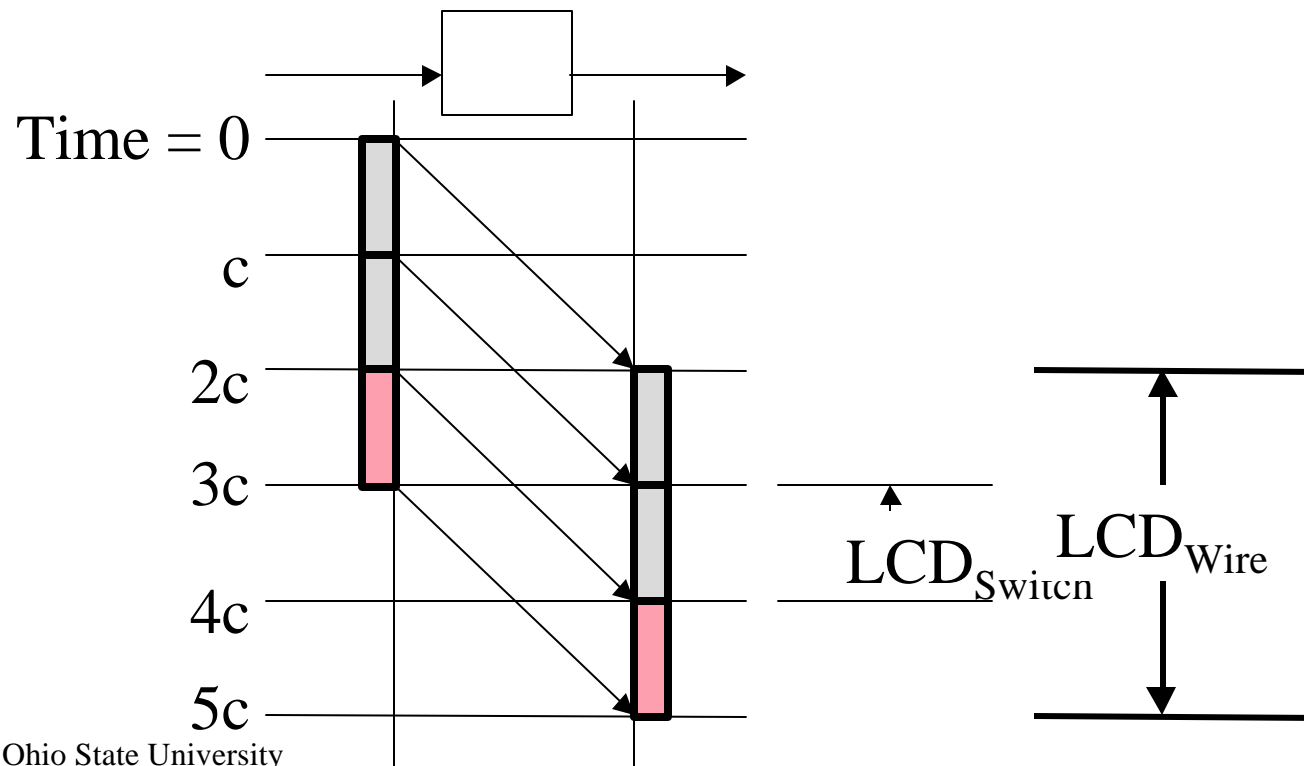
[http://www.cis.ohio-state.edu/~jain/atmf/af\\_lcd.htm](http://www.cis.ohio-state.edu/~jain/atmf/af_lcd.htm)



- ❑ 10 reasons against LCD
- ❑ MIMO vs LCD
- ❑ Measurement Results

# LCD: Definition

- Last Cell Delay:
  - LIFO Latency of the last cell if it is a network
  - FILO Latency of the last cell if it is a wire



# 10. It is too late.

- ❑ Straw-ballot  $\Rightarrow$  Time to remove bugs and not introduce them.
- ❑ No prior experience with this metric

## **9. LCD is not Accepted Anywhere**

- ❑ First introduced at ANSI's May'99 meeting.
- ❑ Not accepted there.

## 8. Contradicts ATM Forum TM Specs

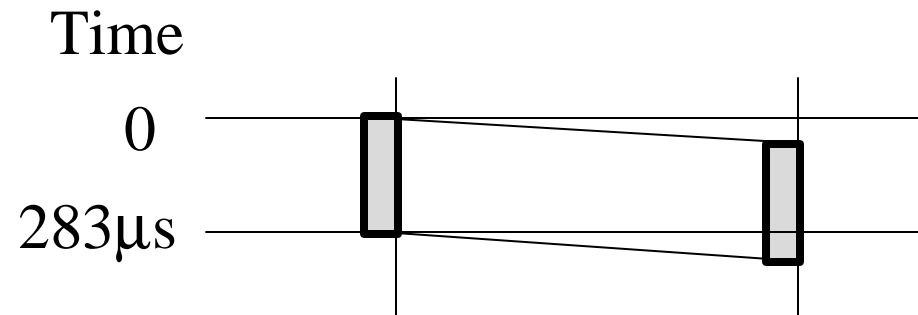
- Cell delay by TM is defined as FIFO for both wire and switches and not LIFO for one and FIFO for other

## 7. Contradicts ATMF Perf-Test Specs

- ❑ Frame reference events FRE1 and FRE2 have already been defined on page 11 of btd-perf-test
- ❑  $FILO = t_{FRE2} - t_{FRE1}$
- ❑ LCD needs yet another set of frame reference events that have the same name but different definition

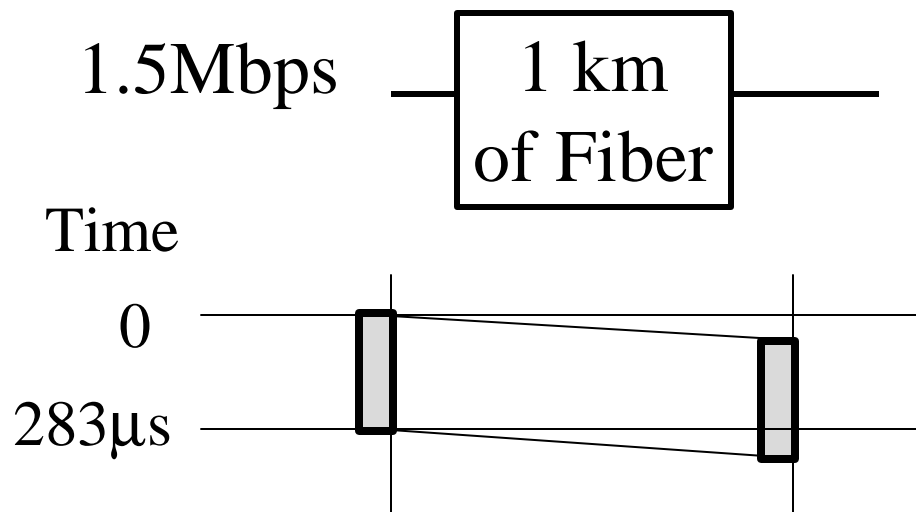
## 6. It is non-intuitive

1.5Mbps 1 km fiber



- ❑ A 1-km spool of fiber has a fixed delay of 5  $\mu$ s
- ❑ Cell time at 1.5 Mbps = 424 bits/1.5 Mbps = 283  $\mu$ s
- ❑ LCDwire = FILO = 288  $\mu$ s

## 5. Arbitrary Wire vs Switch Distinction

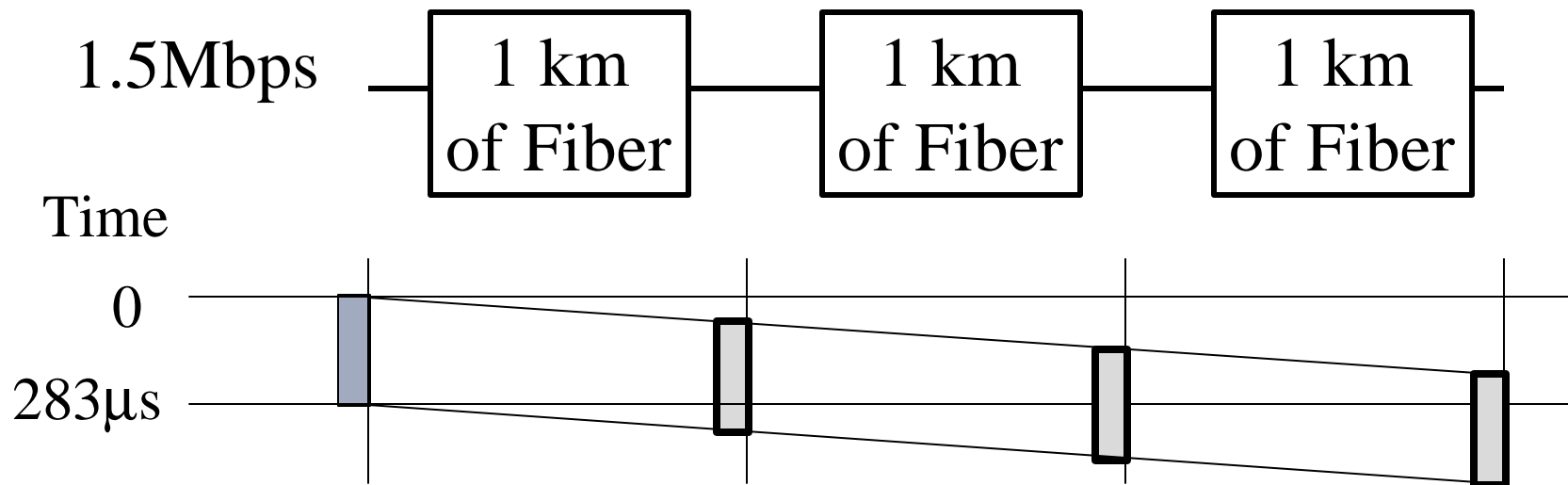


- ❑ A black box containing 1-km spool of fiber has a fixed delay of  $5 \mu\text{s}$
- ❑ Cell time at 1.5 Mbps =  $424 \text{ bits}/1.5 \text{ Mbps} = 283 \mu\text{s}$
- ❑ LCDwire = FILO =  $288 \mu\text{s}$
- ❑ LCDsw = LIFO =  $-278 \mu\text{s}$

## 4. LCD can be Negative

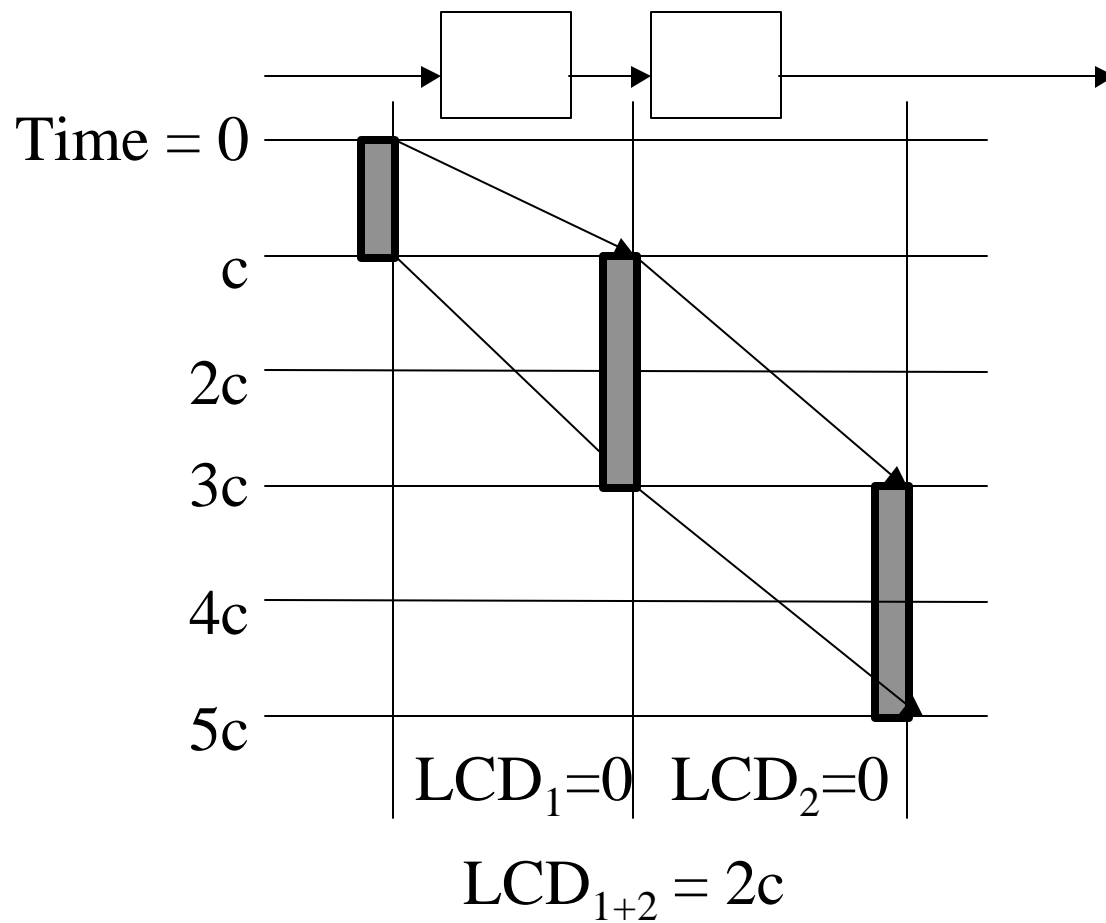
- ❑ All non-store and forward devices can have negative LCD.
- ❑ Examples: Digital amplifiers, multiplexors
- ❑ It is negative for all cut-through switches

### 3. LCD is Not Additive



- ❑  $LCD_{wire} = FILO = 288 \mu s$
- ❑  $LCD_{sw} = LIFO = -278 \mu s$
- ❑  $LCD_{total} = 298$  or  $-268 \mu s$
- ❑  $LCD_{total} \neq LCD_{sw} + LCD_{wire} + LCD_{sw}$

# Non-Additivity



## 2. LCD does Not Account for SUT

- ❑ LCD is extremely workload dependent
- ❑ Output Speed = Input Speed / 2
- ❑ Input Cell Time =  $c$ , Output Cell Time =  $2c$
- ❑ Number of Cells per frame = 3

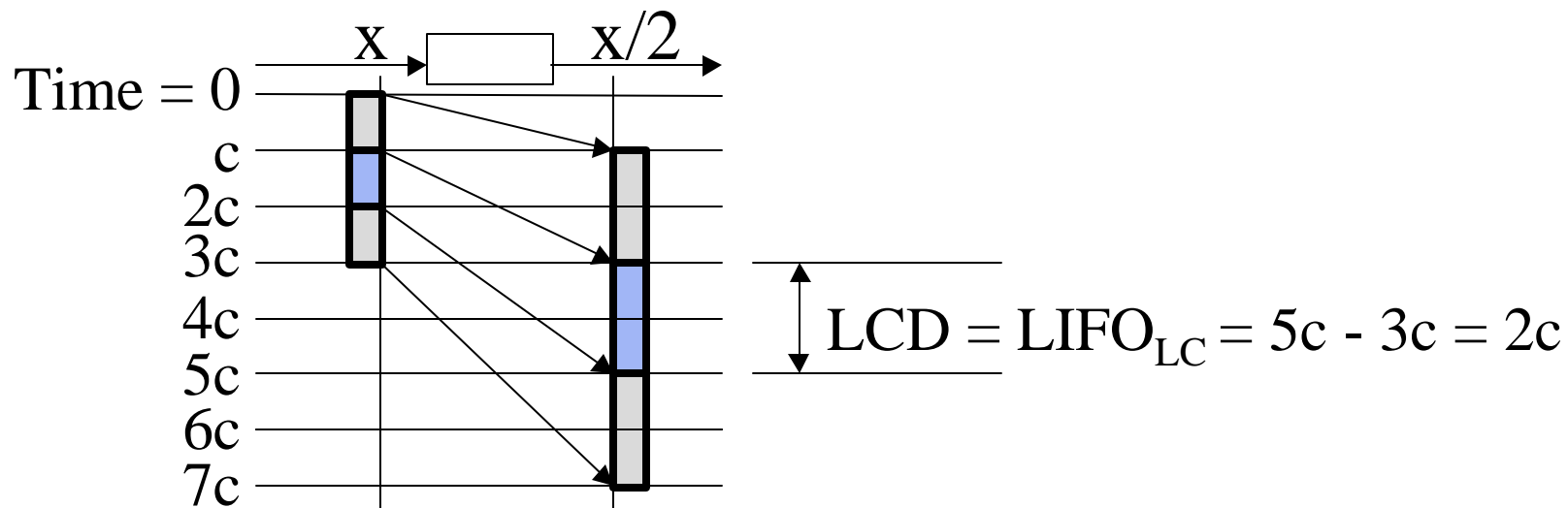
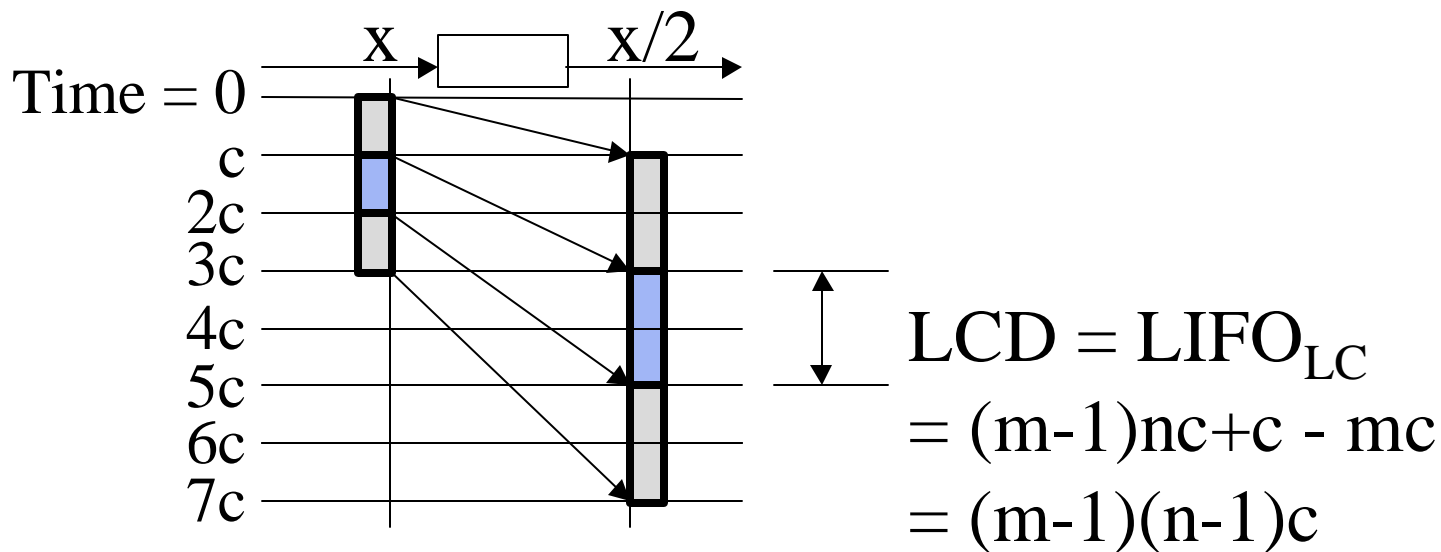


Figure 1

- ❑ Output Speed = Input Speed /n
- ❑ Input Cell Time = c, Output Cell Time = nc
- ❑ Number of Cells per frame = m



**Figure 1**

- ❑ Can get any value by changing frame size m

Frame Size	LCD
1	0
2	99
10	891
100	9801
1000	98901

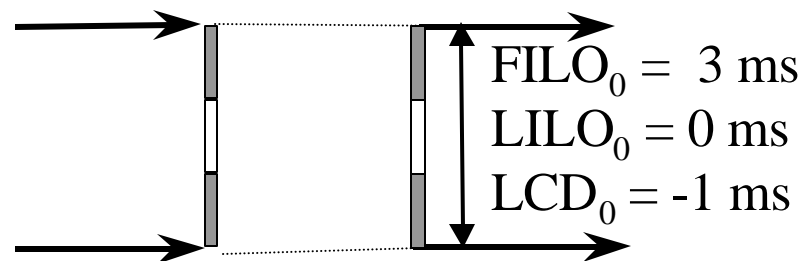
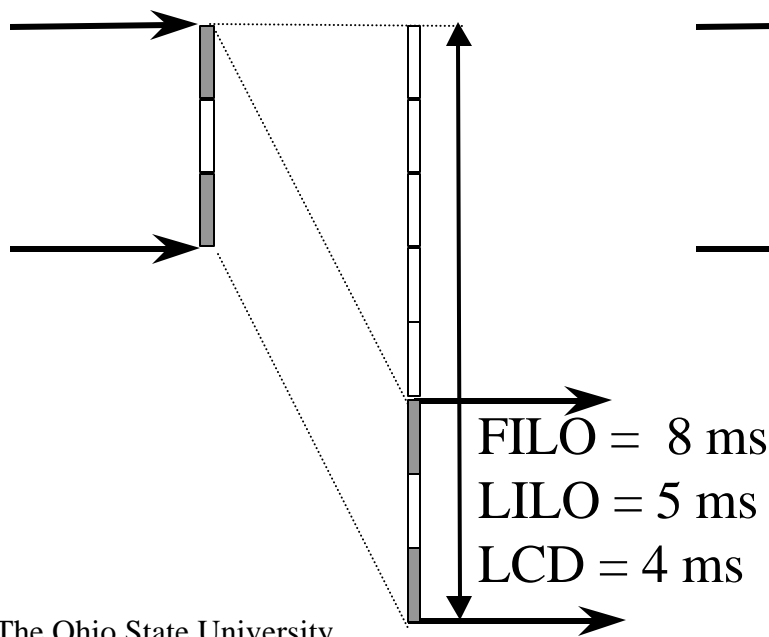
# 1. LILO is Better

- ❑ LILO is additive
- ❑ Same definition applies to both wires and switches
- ❑ LILO is non-negative
- ❑ LILO is already mentioned in the Perf-test spec.
- ❑ There is no need to make any changes.

# MIMO Latency: Definition

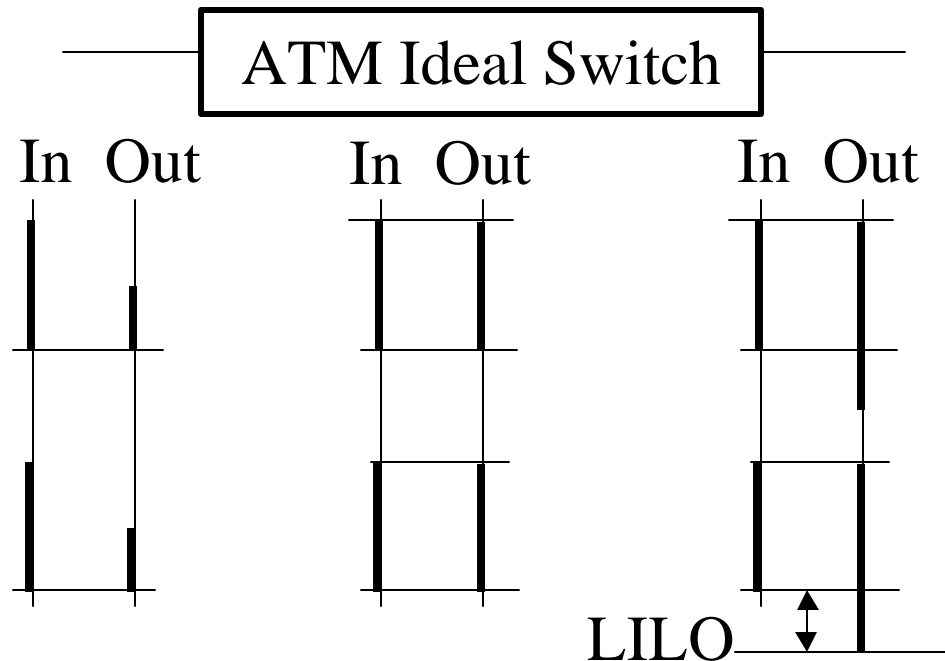
$$\text{MIMO Latency} = \text{FILO} - \text{FILO}_0 = \text{LILO} - \text{LILO}_0 \\ = \text{LCD} - \text{LCD}_0$$

- $\text{FILO}_0$   $\text{LILO}_0$ ,  $\text{LCD}_0$  = Latency thru an ideal network
- Ideal Network = Zero length wire (in many cases)



$$\text{MIMO} = \text{FILO} - \text{FILO}_0 \\ = \text{LILO} - \text{LILO}_0 \\ = \text{LCD} - \text{LCD}_0 \\ = 5 \text{ ms}$$

# Delay Through an Ideal Switch



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

# MIMO vs LCD

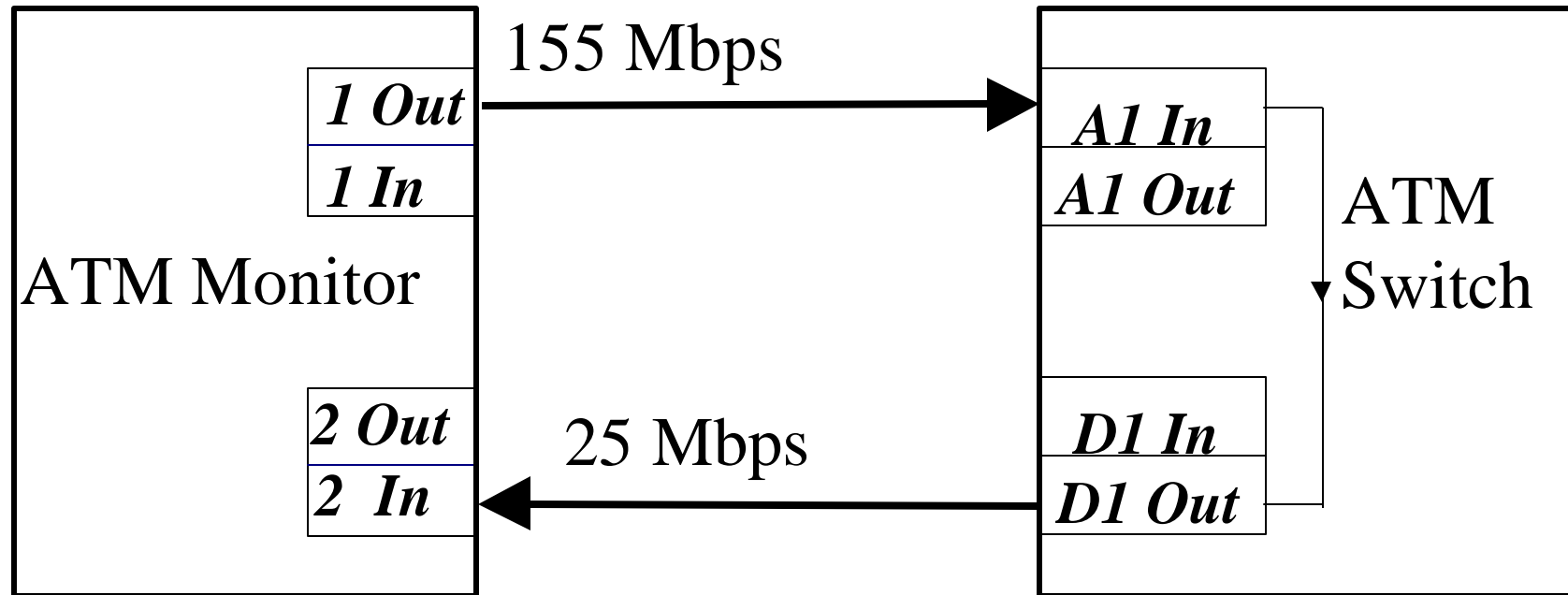
- $MIMO = LCD - LCD_0$ 
  - LCD measures the total delay.
  - $LCD_0$  measures the workload dependent part of the LCD delay.
  - MIMO measures the delay introduced only by switch itself.
- For the m-cell Frame: m depends upon the workload
  - $LCD = (m-1)(n-1)c$ ,  $LCD_0 = (m-1)nc - mc$ ,
  - $MIMO = LCD - LCD_0 = 1c$

# LCD vs MIMO

Frame Size	LCD	LCD0	MIMO
1	0	-1	1
2	99	98	1
10	891	890	1
100	9801	9800	1
1000	98901	98900	1

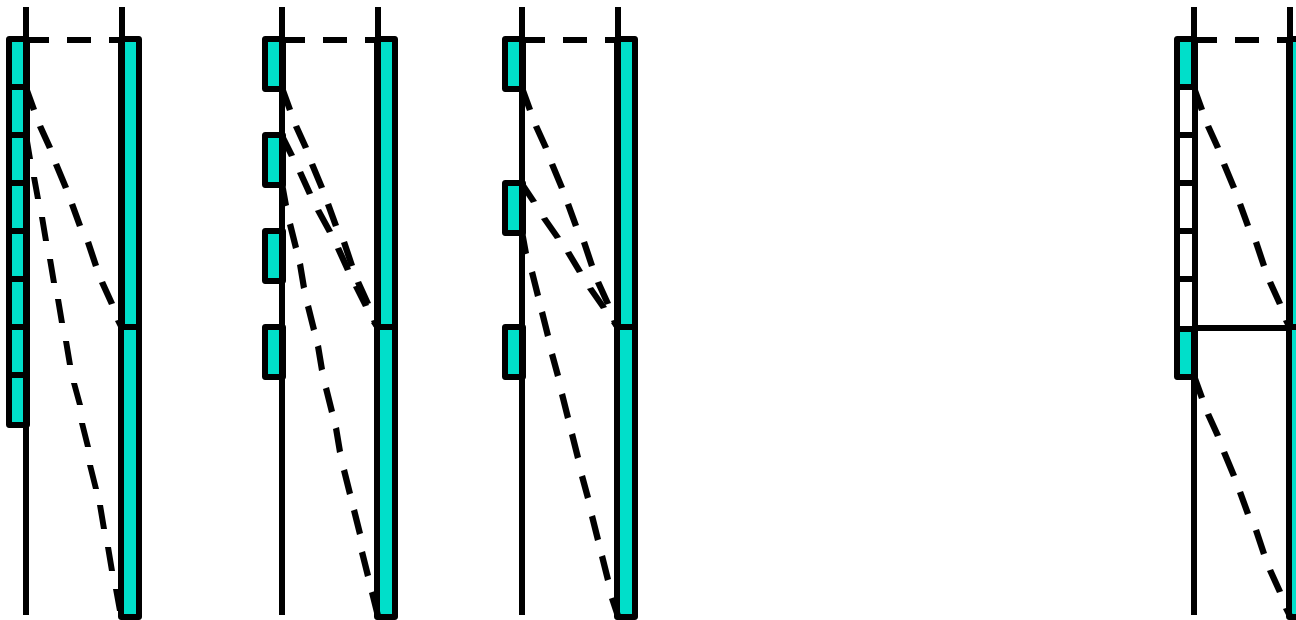
- LCD depends upon the frame size  
MIMO is independent of the framesize

# 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



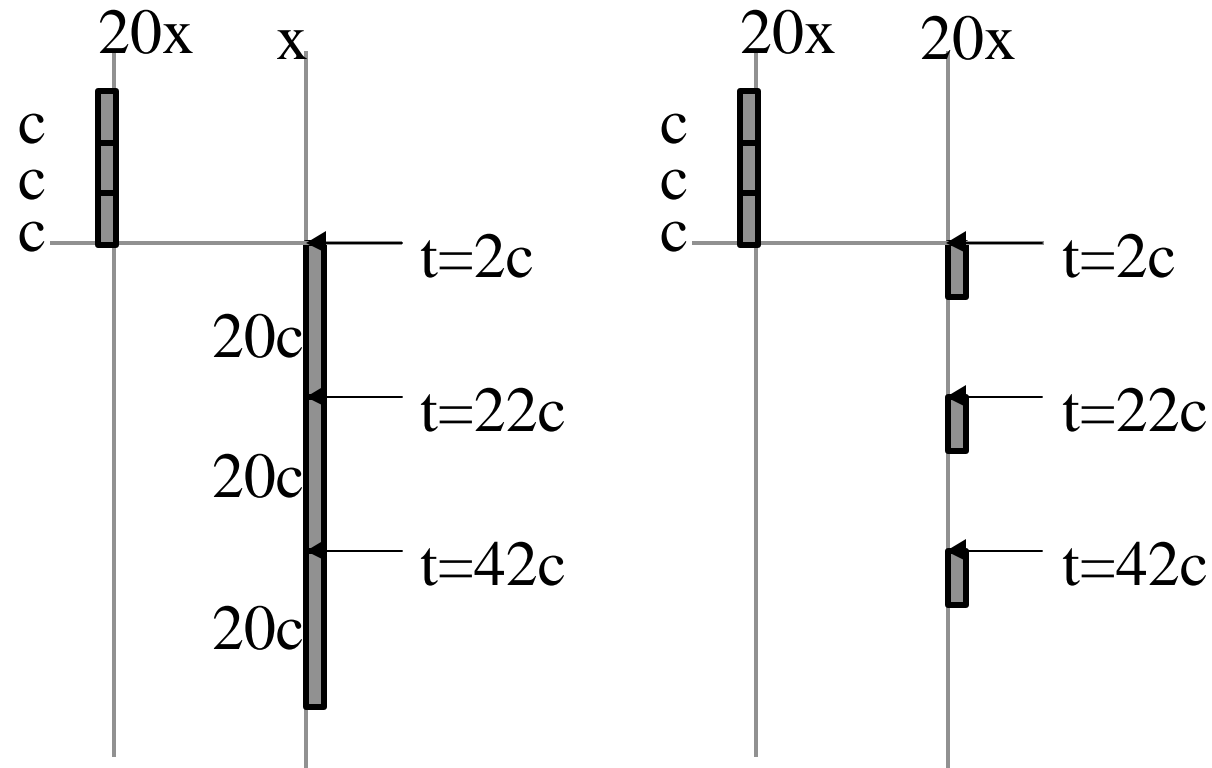
# Measurement Results

- ❑ Input 155Mbs, Output 25Mbs, 32-cell frame
- ❑ LCD = LILO - Cell output time = LILO - 16.9  $\mu$ s
- ❑ LCD and FILO depend heavily from frame pattern
- ❑ MIMO indicates the switch contribution in the delay

Test No.	Frame Pattern	LILO <sub>0</sub>	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

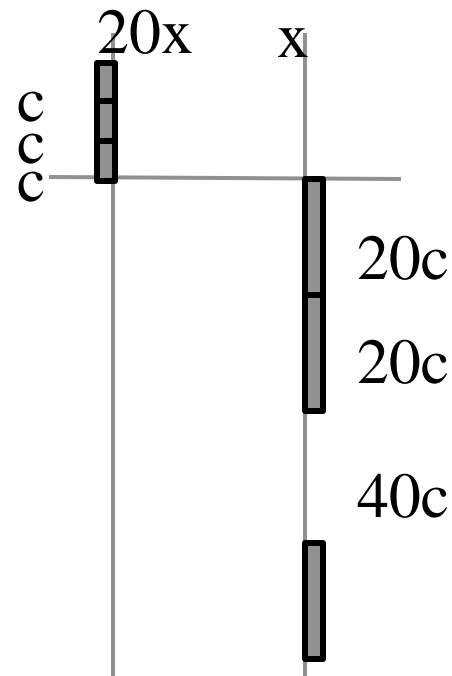
# Non-Accountability: Example 2



(a) MIMO =  $2c$   
LCD =  $39c$

(b) MIMO =  $40c$   
LCD =  $39c$

□ 2nd system has unnecessary delays but has same LCD.



$$\text{MIMO} = 42c$$

$$\text{LCD} = 79c$$

- Compared to the previous system, this system has an extra gap of  $40c$ . MIMO and LCD go up by  $40c$ .

# Systems with Internal Bottleneck

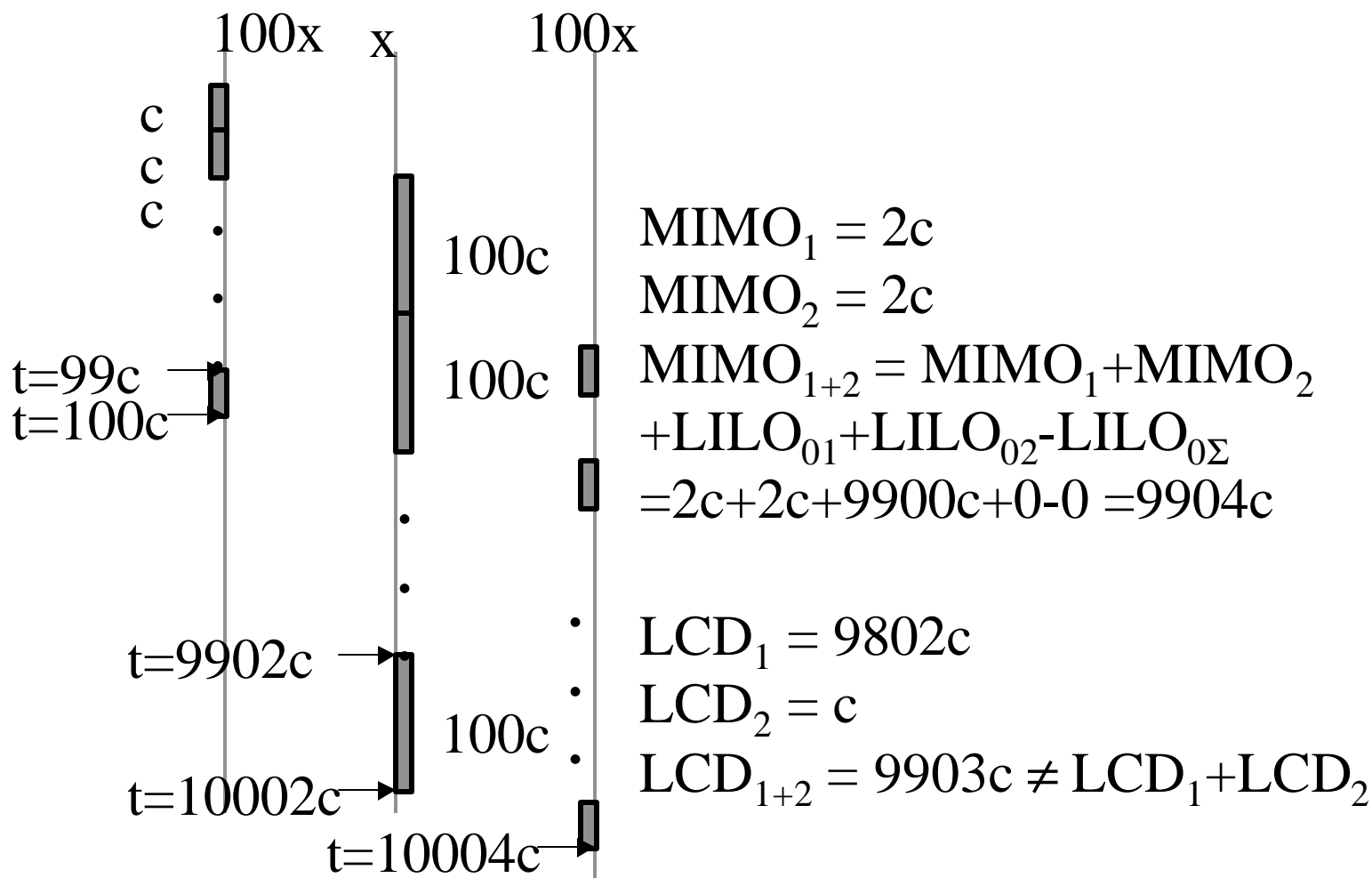
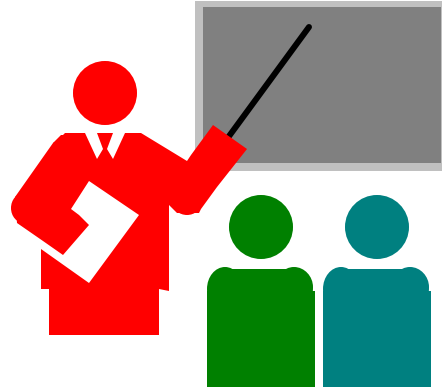


Figure 6

# Summary: LCD

10. It is too late.
9. LCD is not Accepted Anywhere
8. Contradicts ATMF TM Specs
7. Contradicts ATMF Perf-Test Specs
6. It is non-intuitive
5. Arbitrary Wire vs Switch Distinction
4. LCD can be Negative
3. LCD is Not Additive
2. LCD does Not Account for SUT
1. LILO is Better

# Conclusions



- ❑ LCD is significantly affected by the workload
- ❑ FILO is meaningless if large gaps in the frames
- ❑ LCD is meaningless if large number of back-to-back frames