# 99-0368
# On LCD and MIMO

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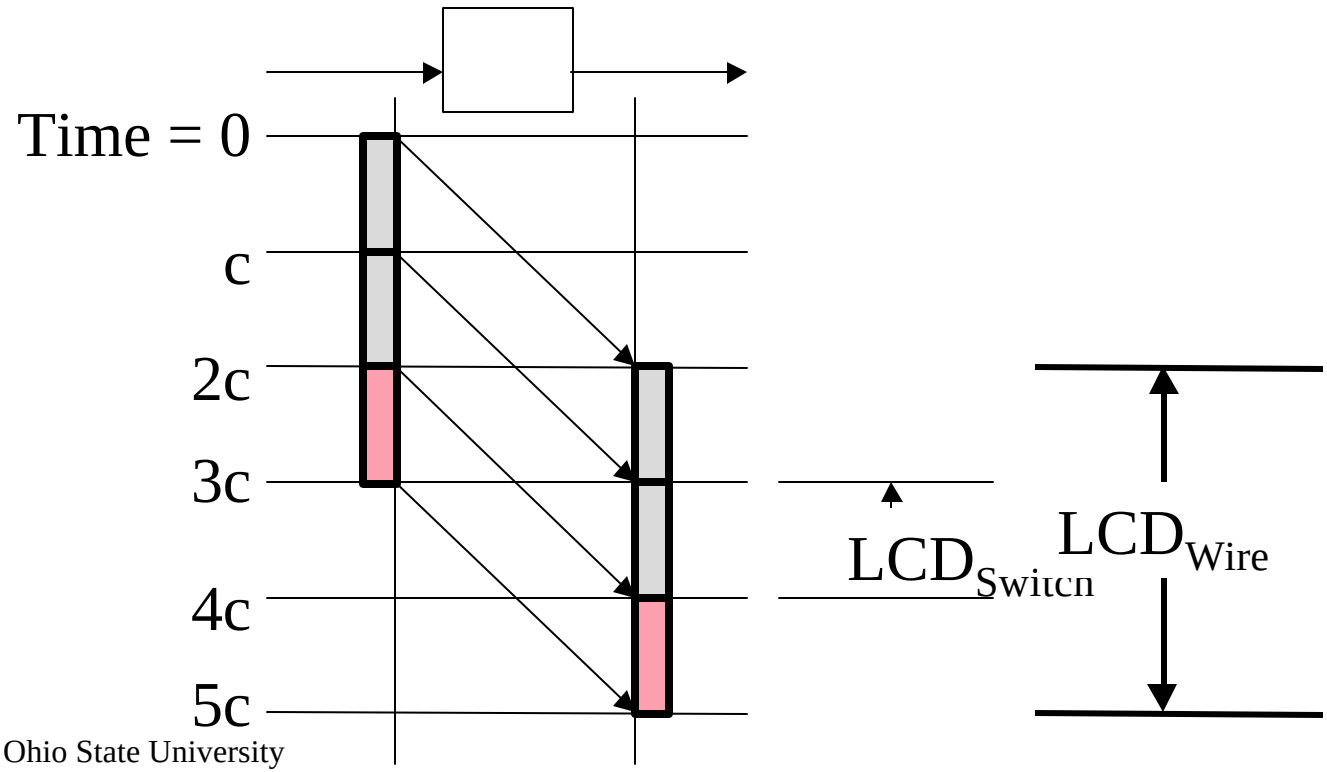
# Overview

- 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 ⇒ 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.

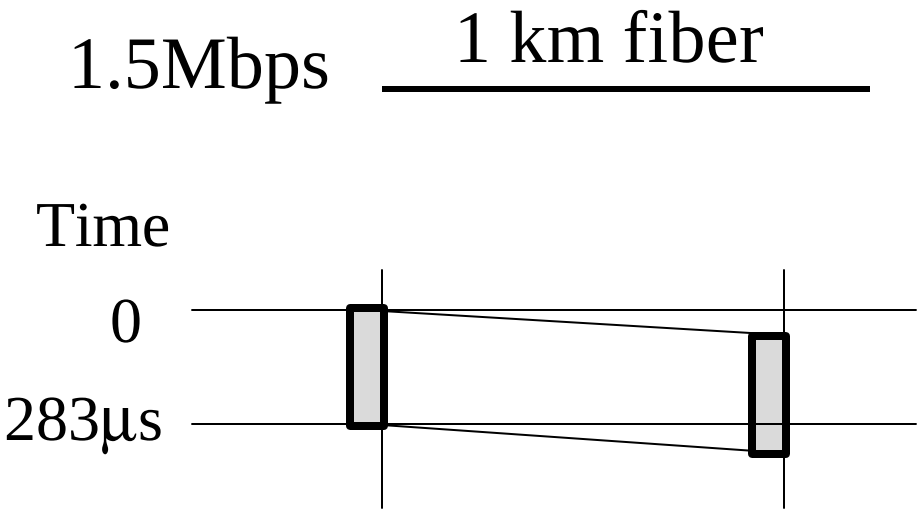
# 8. Contradicts ATMF TM Specs

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

# 7. Contradicts ATMF Perf-Test Specs

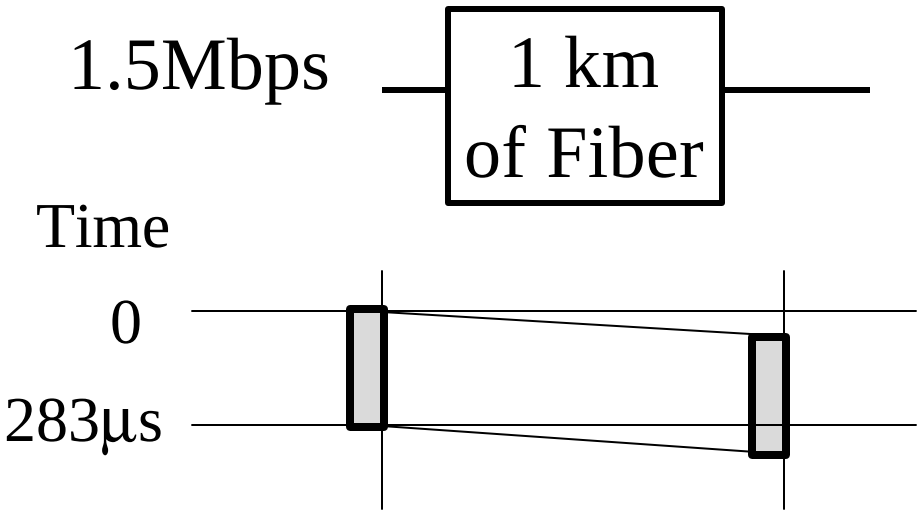
- Frame reference events FRE1 and FRE2 have already been defined on page 11 of btd-perf-test
- FILO = $t_{FRE2} - t_{FRE1}$
- LCD needs yet another set of frame reference events that have the same name but different definition

# 6. It is non-intuitive




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

# 5. Arbitrary Wire vs Switch Distinction

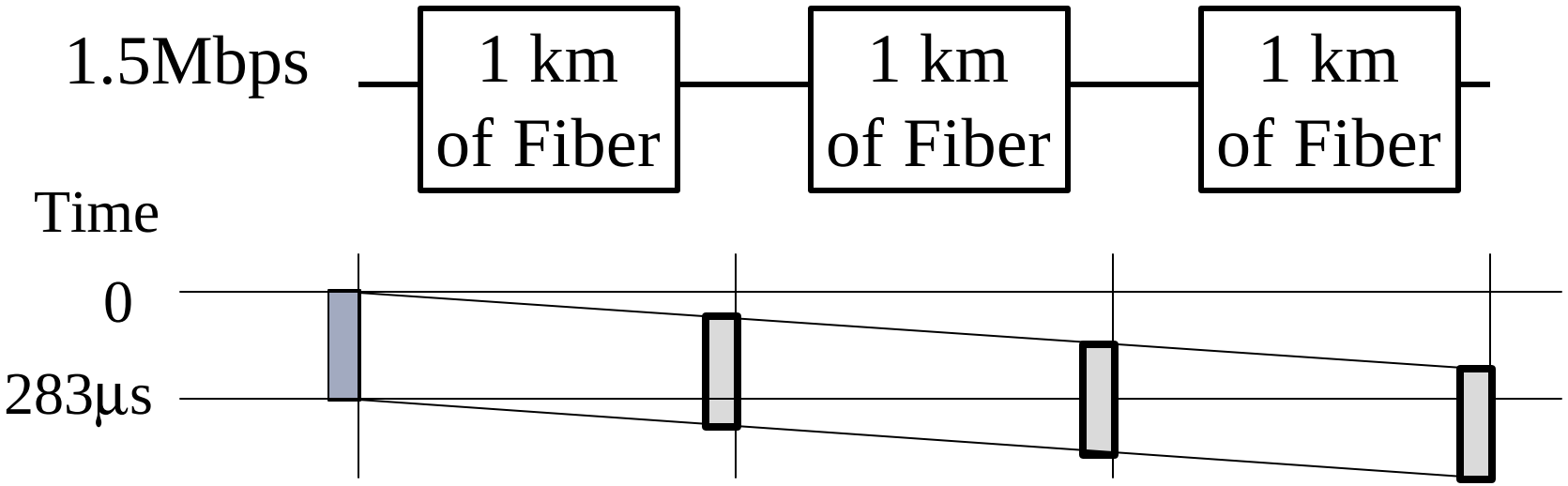



- A black box containing 1-km spool of fiber has a fixed delay of 5 µs
- Cell time at 1.5 Mbps = 424 bits/1.5 Mbps = 283 µs
- LCDwire = FILO = 288 µs
- LCDsw = LIFO = -278 µs

# 4. LCD can be Negative

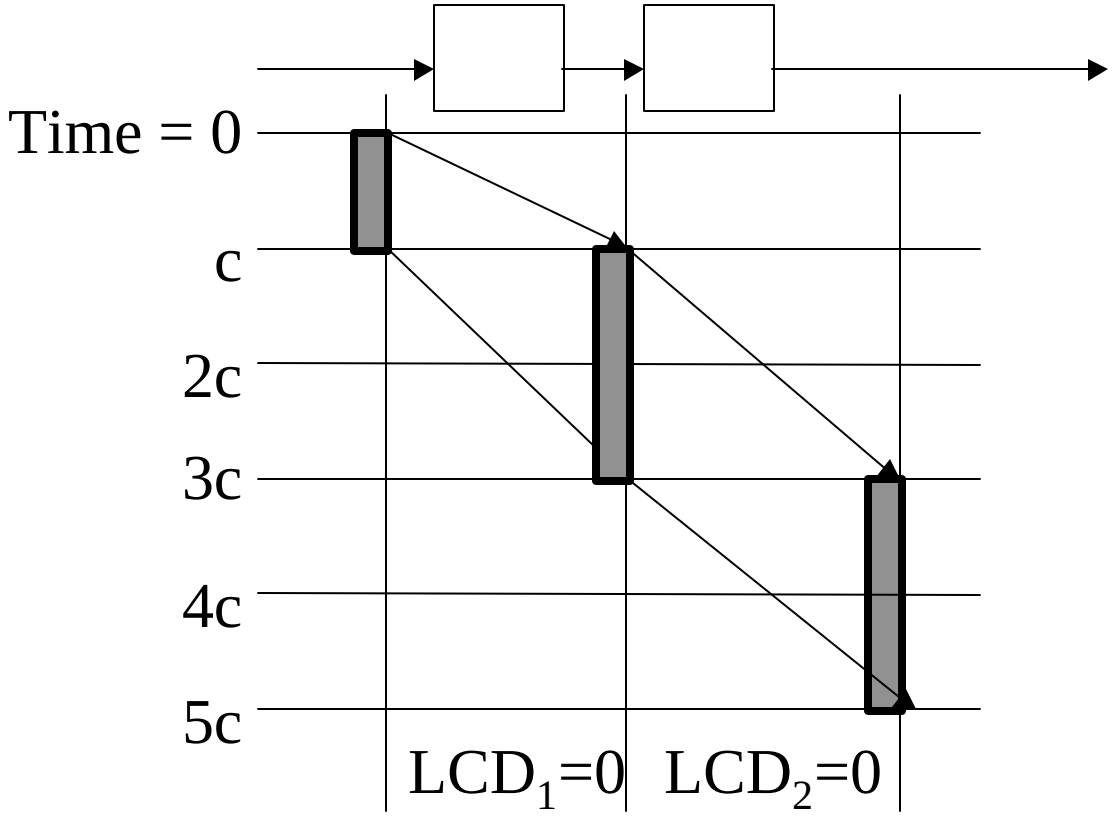
- All non-store and forward devices can have negative LCD.
- Examples: Digital amplifiers, multiplexors
- It is negative for all cut-through switches

# 3. LCD is Not Additive




- LCDwire = FILO = 288 μs
- LCDsw = LIFO = -278 μs
- LCDtotal = 298 or -268 μs
- LCDtotal ≠ LCDsw+LCDwire+LCDsw

# Non-Additivity




$LCD_{1+2} = 2c$

**Figure 3**

# 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

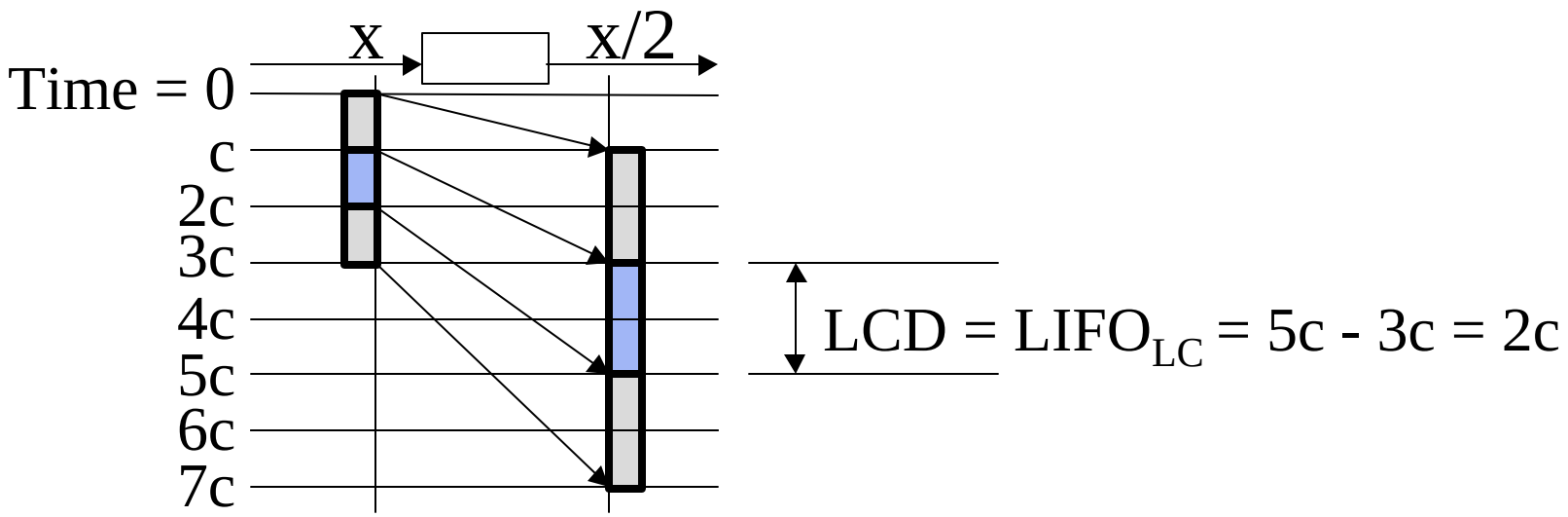
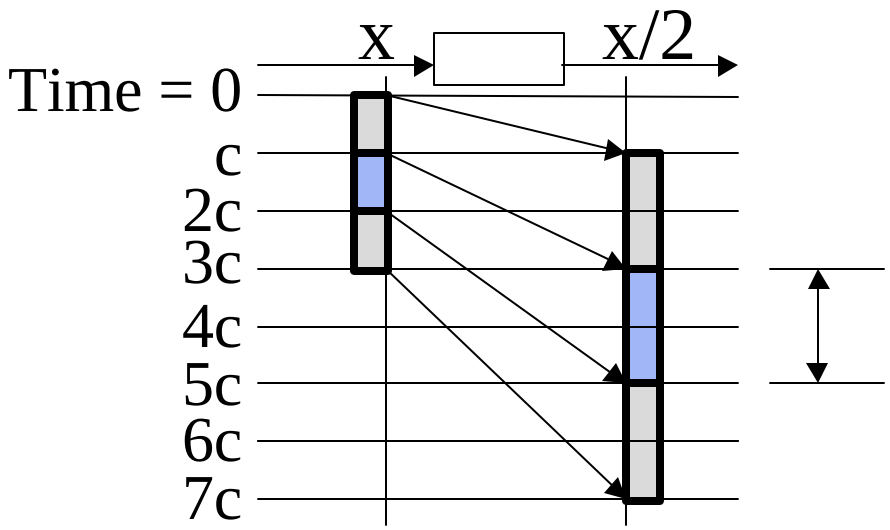



**Figure 1**

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




$$LCD = LIFO_{LC}$$
$$= (m-1)nc+c - mc$$
$$= (m-1)(n-1)c$$

**Figure 1**

- Can get any value by changing frame size m

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

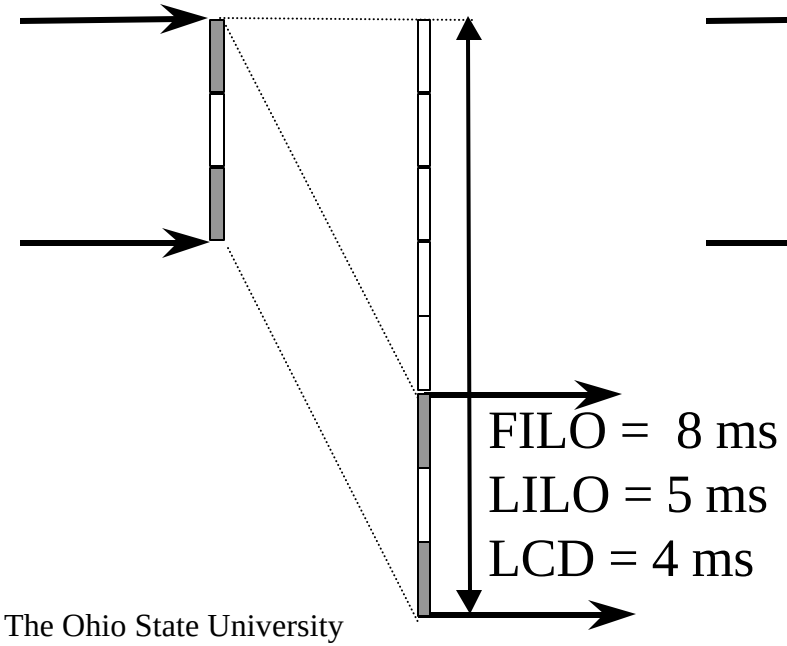
# 1. LILO is Better

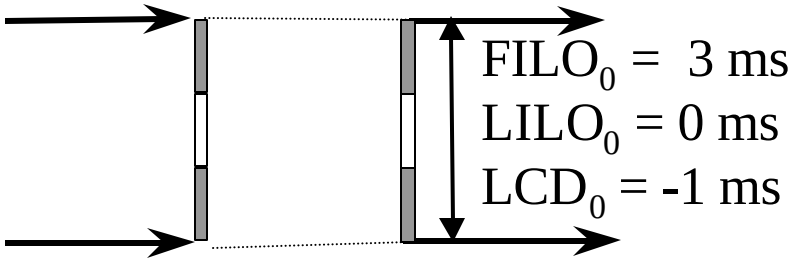
- LILO is additive
- Same definition applies to both wires and switches
- LILO is non-negative
- LILO is already mentioned in the Perf-test spec.
- There is no need to make any changes.

# MIMO Latency: Definition

MIMO Latency = FILO – $FILO_0$ = LILO - $LILO_0$
= LCD - $LCD_0$

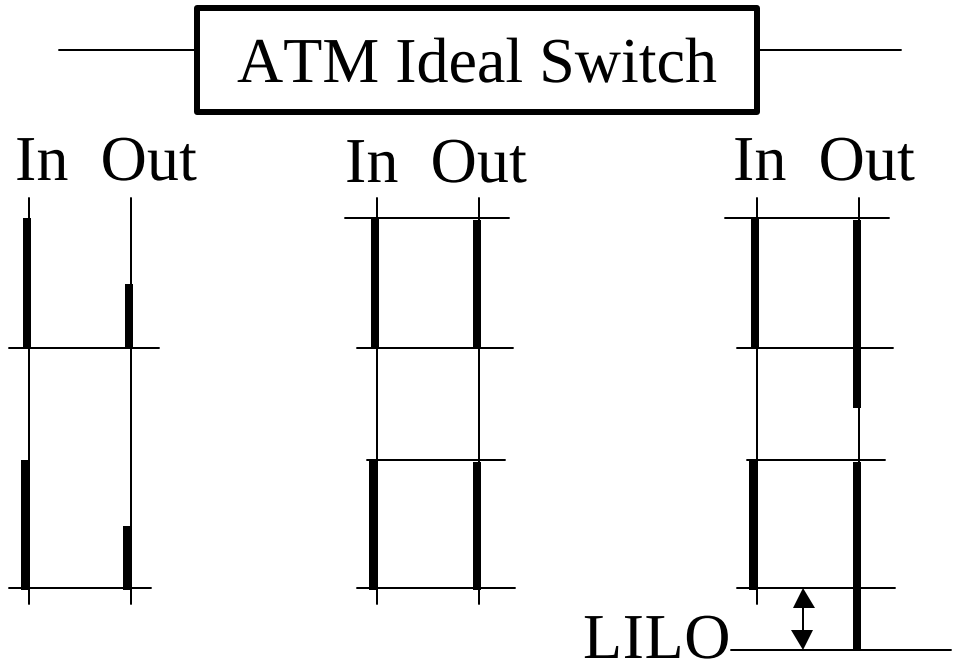
- $FILO_0$ $LILO_0$, $LCD_0$ = Latency thru an ideal network
- Ideal Network = Zero length wire (in many cases)




MIMO = FILO - $FILO_0$
= LILO -$LILO_0$
= LCD - $LCD_0$
= 5 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

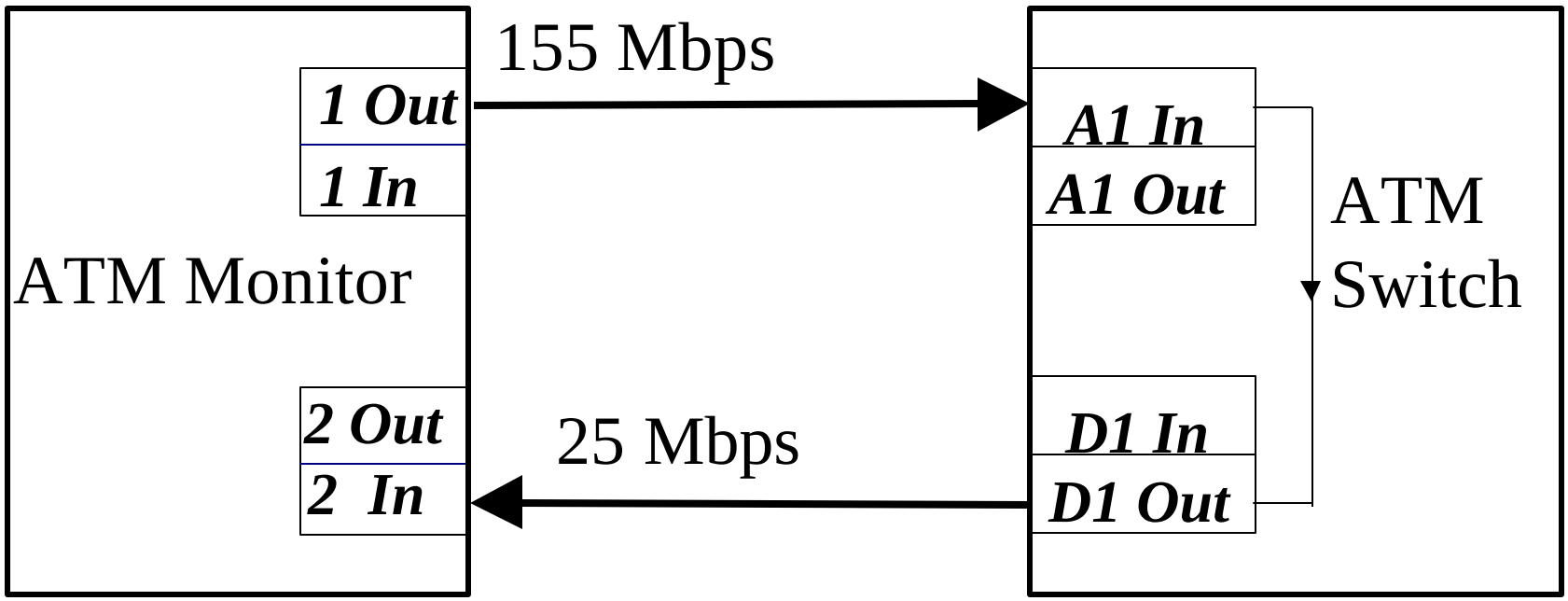
- MIMO = LCD - $LCD_0$
  - LCD measures the total delay.
  - $LCD_0$ measures the workload dependent part of the LCD delay.
  - MIMO measures the delay introduced only by switch itself.
- For the m-cell Frame: m depends upon the workload
  - LCD = (m-1)(n-1)c, $LCD_0$ = (m-1)nc-mc,
  - MIMO = LCD - LCD0 = 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 |

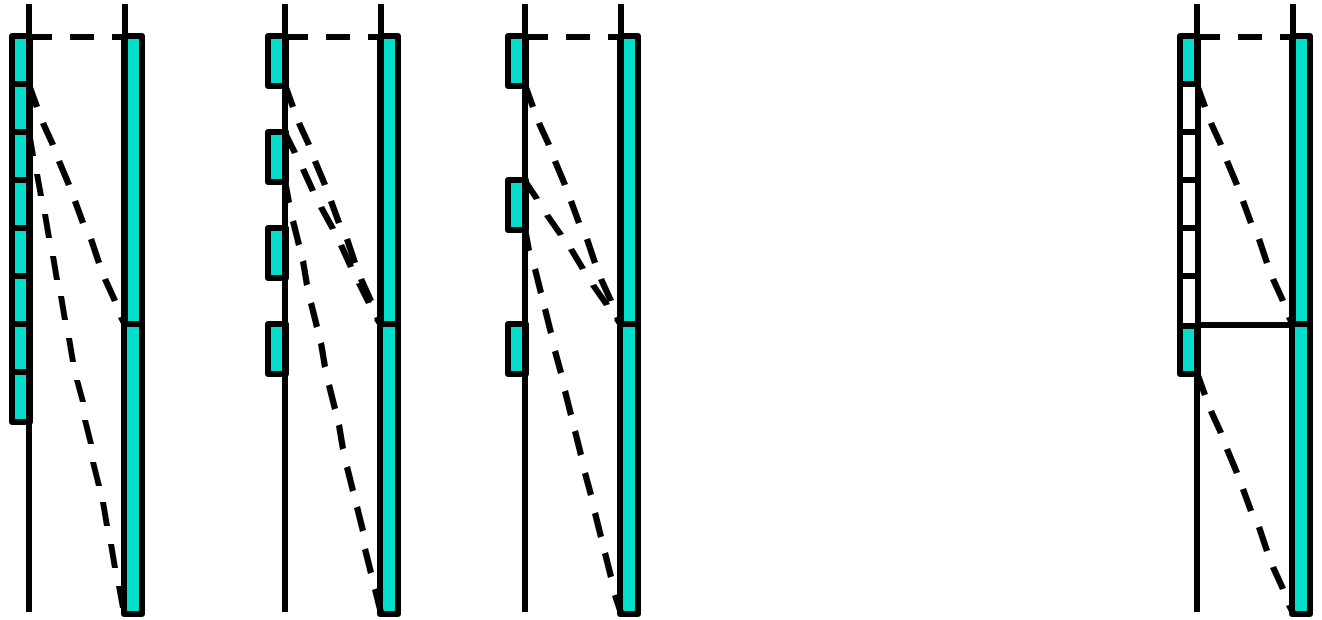
- LCD depends upon the frame size
  MIMO is independent of the framesize

# 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



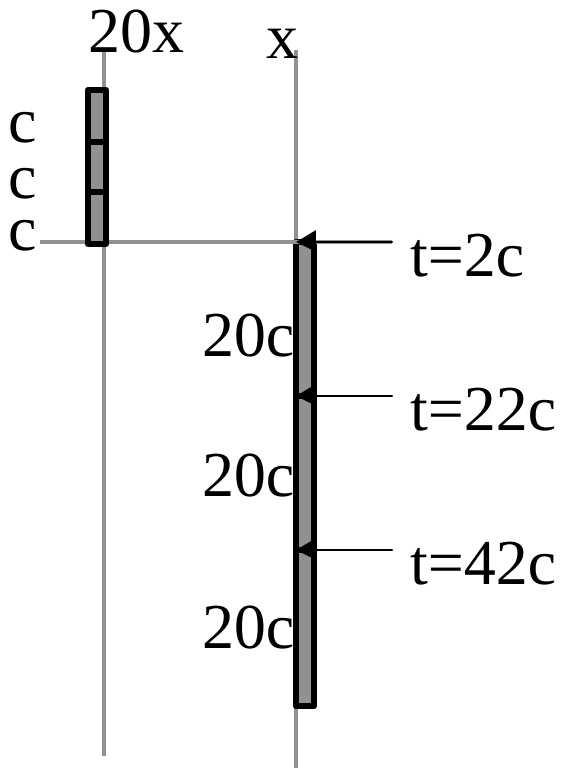
# Measurement Results

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

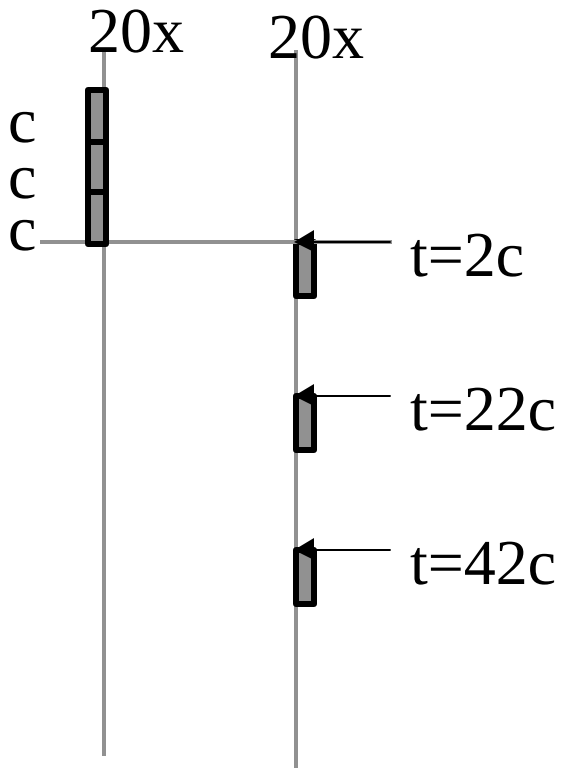
| Test No. | Frame Pattern | $LILO_0$ | LILO | FILO | MIMO |
|---|---|---|---|---|---|
| 1 | No gap | 351.71 | 385.01 | 563.3 | 33.3 |
| 2 | 1-cell gaps | 263.98 | 295.78 | 561.8 | 31.8 |
| 3 | 2-cell gaps | 176.25 | 209.05 | 562.8 | 32.8 |
| 4 | 3-cell gaps | 88.52 | 119.82 | 561.3 | 31.3 |

All times are in microseconds

# Non-Accountability: Example 2

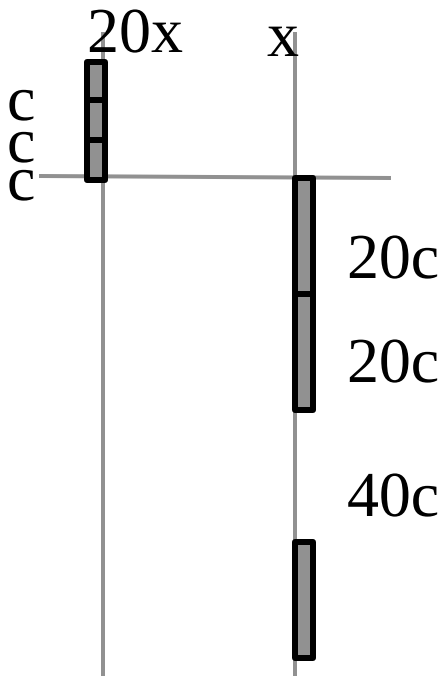



(a) MIMO = 2c
LCD = 39c




(b) MIMO =40c
LCD = 39c

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

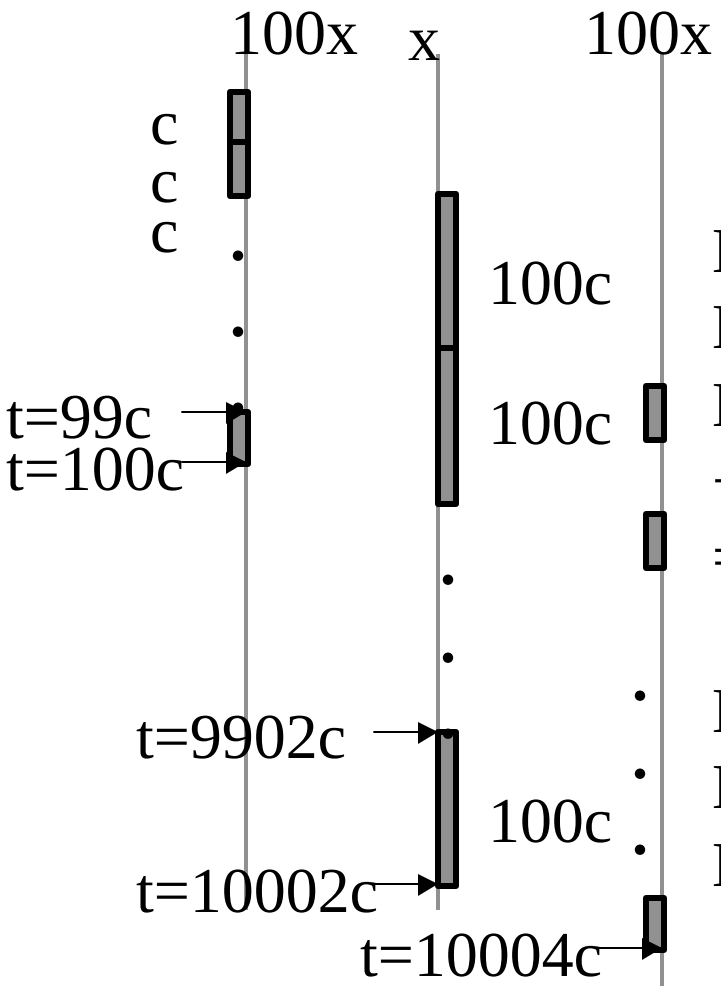



MIMO = 42c

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




$MIMO_1 = 2c$

$MIMO_2 = 2c$

$MIMO_{1+2} = MIMO_1 + MIMO_2 + LILO_{01} + LILO_{02} - LILO_{0\Sigma}$

$= 2c + 2c + 9900c + 0 - 0 = 9904c$

$LCD_1 = 9802c$

$LCD_2 = c$

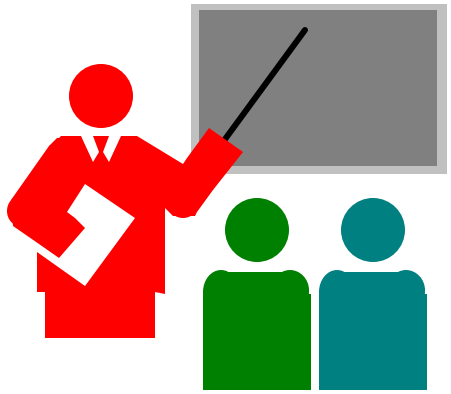
$LCD_{1+2} = 9903c \neq LCD_1 + LCD_2$

**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