Rate Adaptation in Visual MIMO

(Camera based Optical Wireless)

Ashwin Ashok

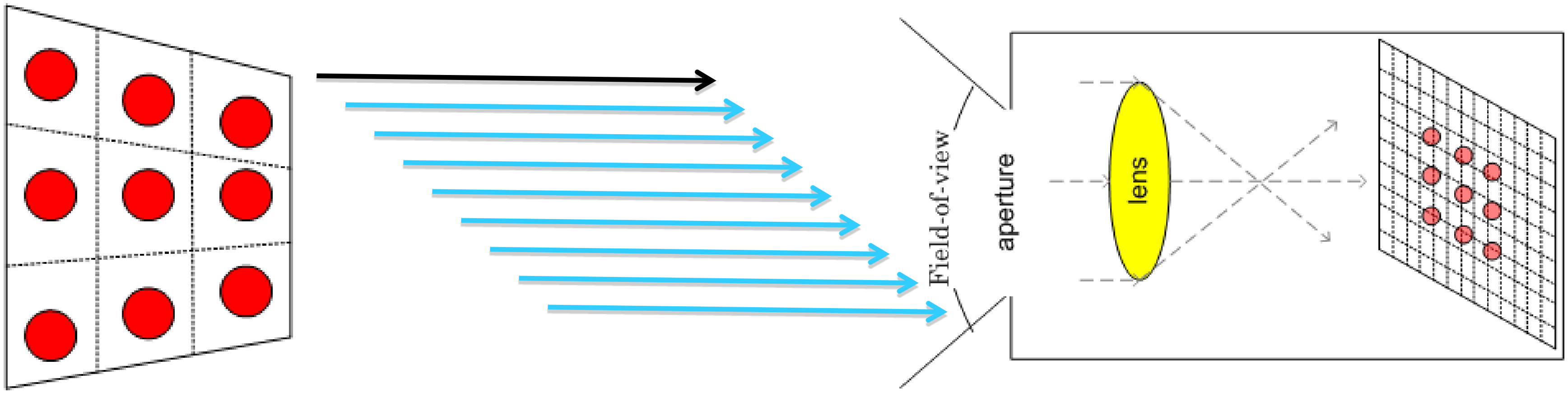
WINLAB

Rutgers-The State University of New Jersey

with Marco Gruteser, Narayan Mandayam,
Michael Varga, Taekyoung Kwon,
Kristin Dana and Wenjia Yuan

IEEE SECON'2011

Visual MIMO



Transmitter Array

Receiver Array

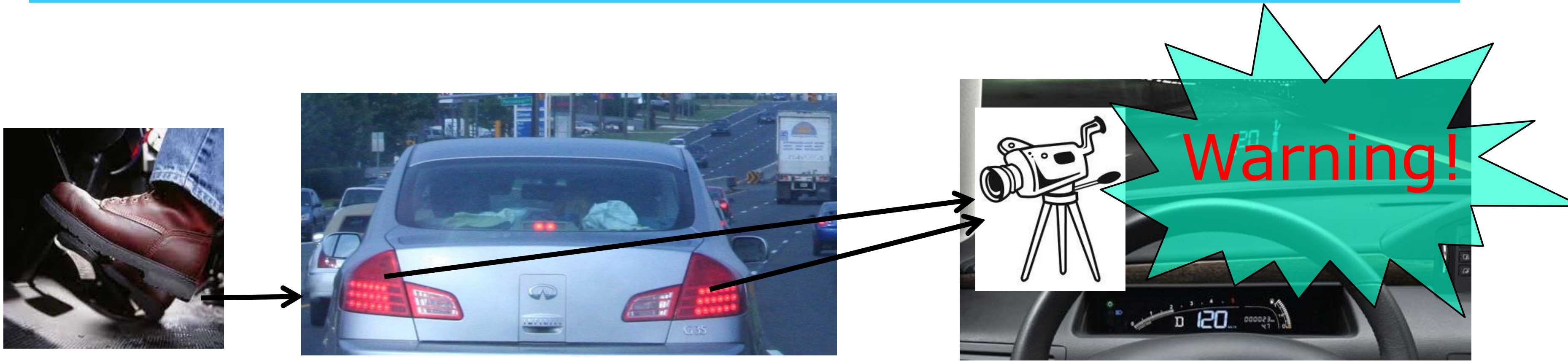
Multiplex bits over parallel channels ➔ scale data-Rate by N_m

same bits on all channels (Diversity) ➔ scale SNR by N_d

$$C = N_m (W \log_2 [1 + N_d \gamma])$$

$\gamma = SNR$ [Ashok, et al-Mobicom'10]

An example..V2V



(-)LOS required : mobility can kill data rate

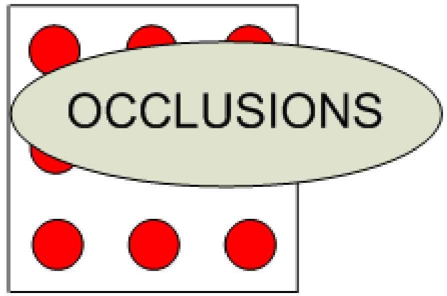
(-)Optical channel distortions : limited range

(+) ‘Rate of change’ in optical channel < RF

Rate Adaptation!

Rate Adaptation Challenges

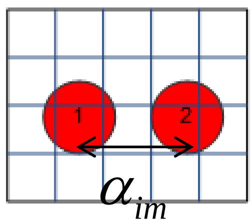
- Visibility



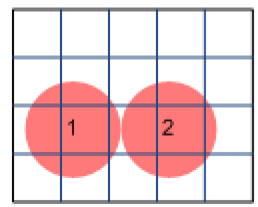
Visibility Index set (n=LED index)

$$V(n) = \begin{cases} 1 \rightarrow visible \\ 0 \rightarrow occluded \end{cases}$$

- Lens Blur



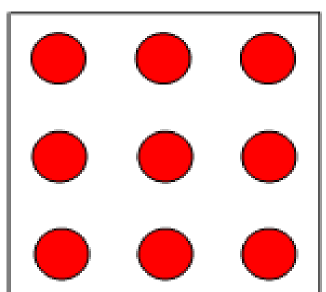
resolvable



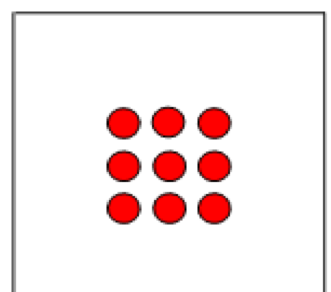
unresolvable

Threshold pixel separation

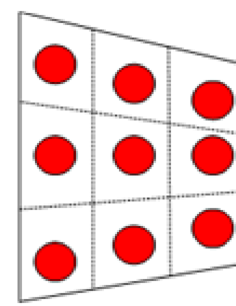
- Perspective Distortions



Short distance



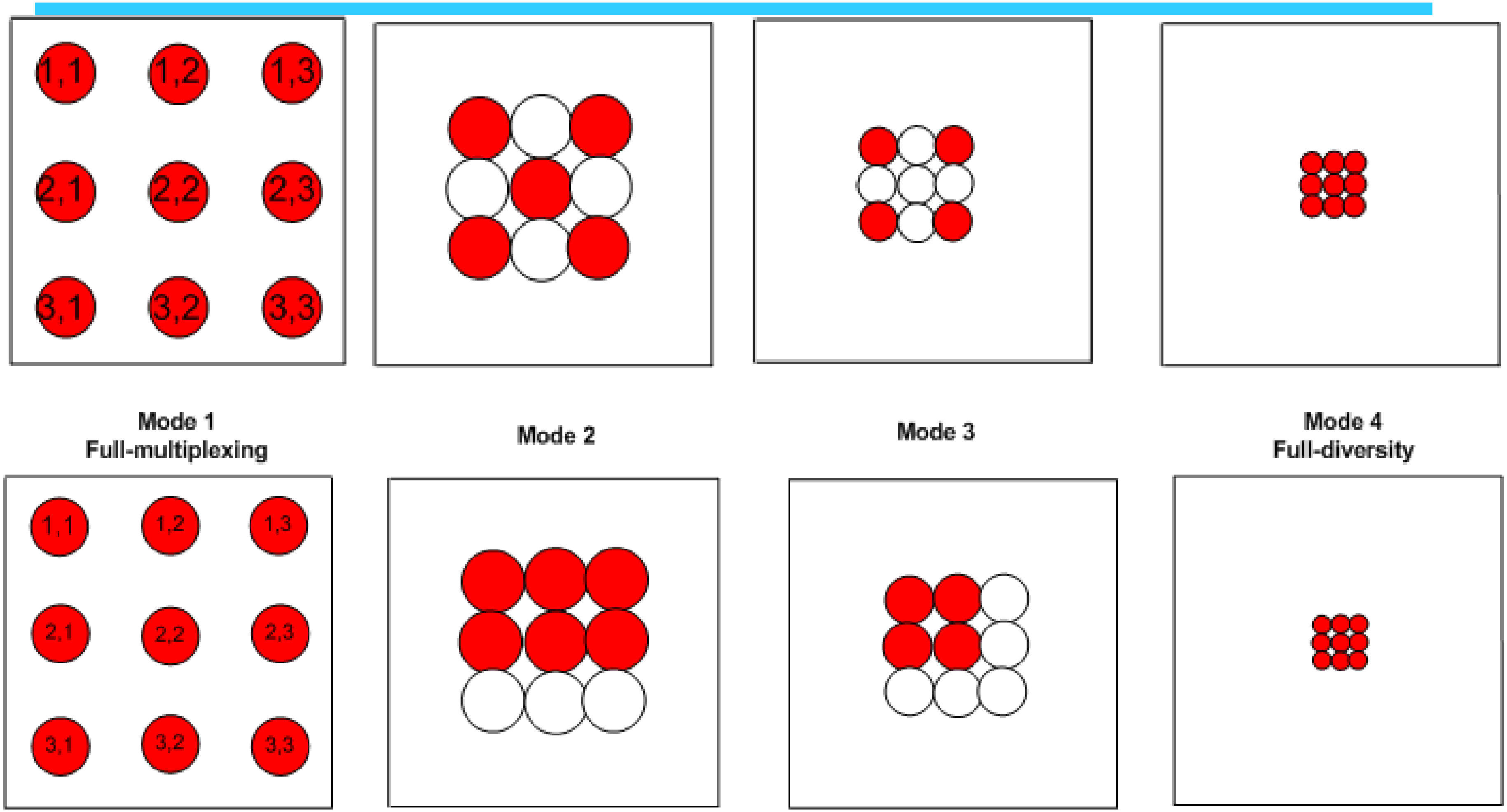
Large distance



Angular view

RUTGERS

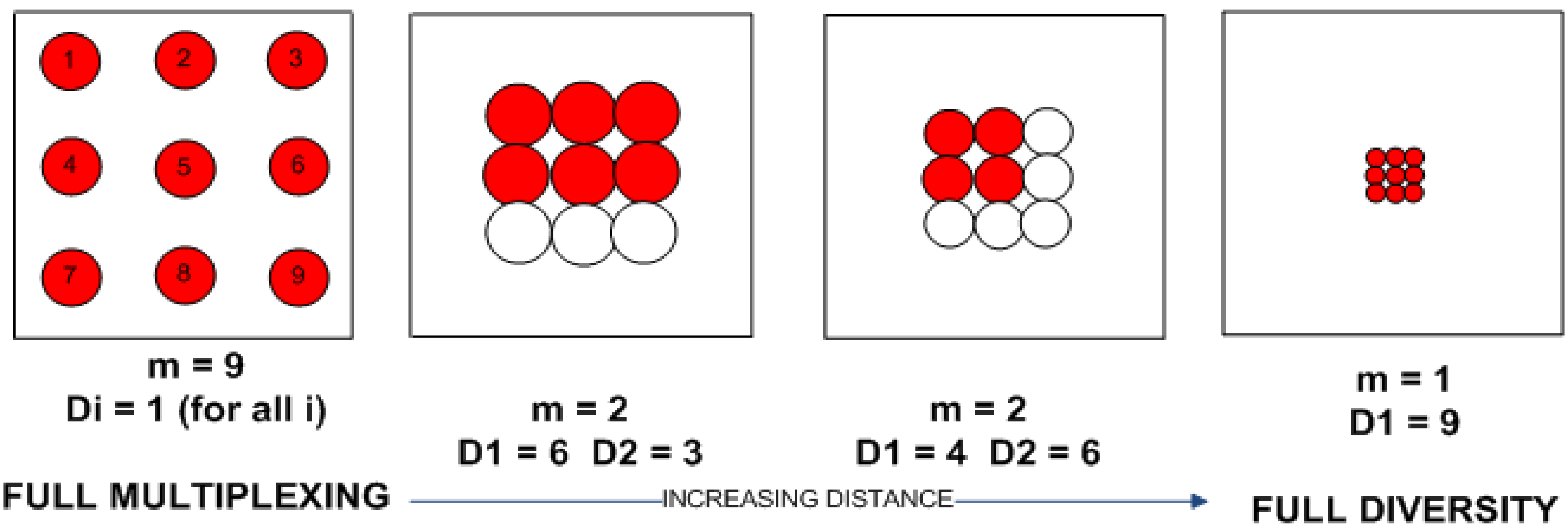
Transmission Modes



Formulating the Modes

set of m non-overlapping subsets chosen from the N LEDs of the array where each set $i(i=1,2,3...m)$ is a group of D_i LEDs such that $\sum_{i=1}^{m} D_i \leq N$

→ m multiplex D_i diversity



Visual MIMO Rate Adaptation (VMRA)

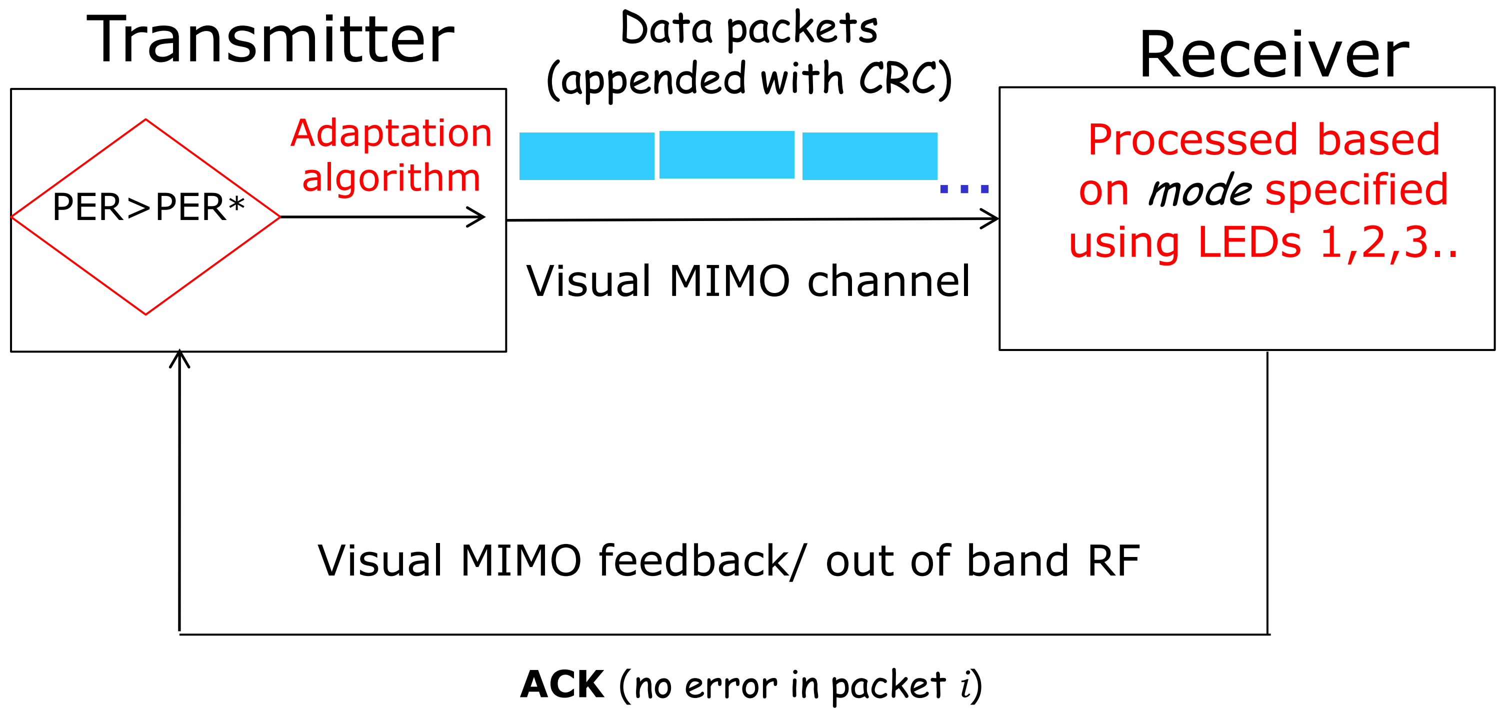
Problem:

"efficiently choose a transmission *mode* that maximizes data throughput"

Constraints: errors due to

- Visibility issues – occlusion of camera view
- Perspective distortions - changing distance
- Resolvability issues - Lens blur

VMRA: Methodology

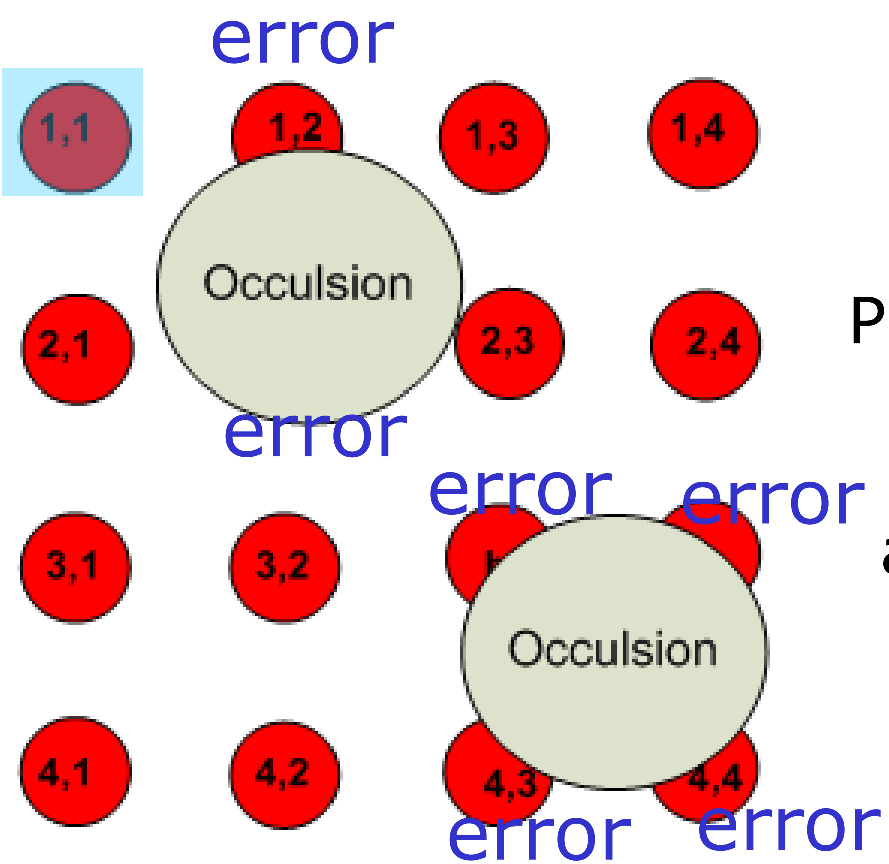


Which of the LEDs are visible?
Using the visible LEDs, what is the *mode* to be set?

Proposed solutions

- Exhaustive visibility search
  - temporal probing using training sequence
  - sequentially search through all LEDs for errors
- Probe VMRA
  - spatial probing using repeated bit patterns
  - Use ‘smart’ spatial patterns to detect LEDs in error
- Index VMRA
  - Use a block CRC scheme
  - Use separate CRCs for independent blocks of bits sent from each LED
  - Index LEDs in error over each iteration

Exhaustive search

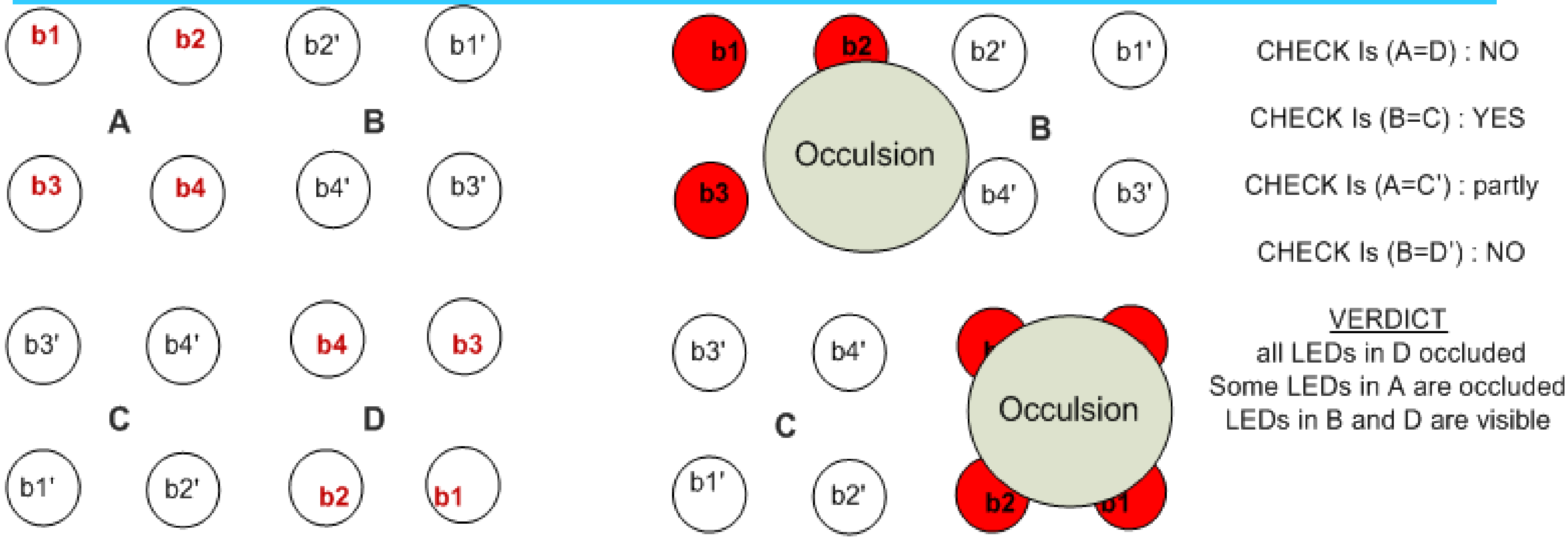


Each LED transmits a training sequence
'One after the other'
Prior to data transmission

Training sequence is appended with a check-sum

INEFFICIENT !

Probing

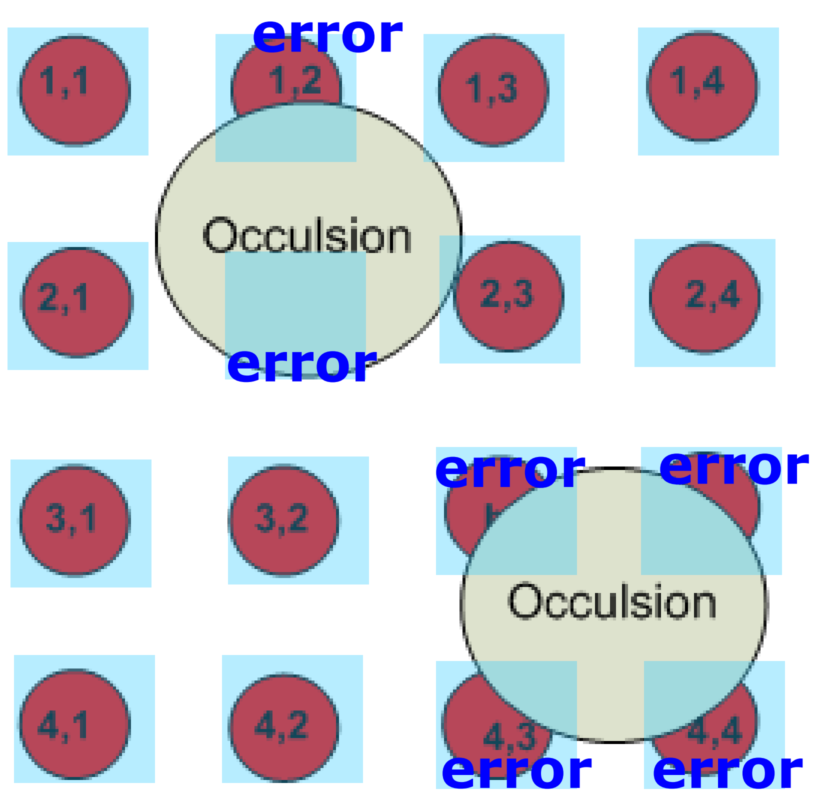


{b1',b2',b3',b4'} = complement of {b1,b2,b3,b4}

faster than exhaustively searching all LEDs

Designing 'smart' spatial patterns for different LED array configurations is non-trivial !

Indexing



- All LEDs transmit in parallel
- Each LED transmits a packet appended with a CRC
- No training sequence required
- Erroneous LEDs are found during data transmission => minimal overhead

Trace based Simulation

ground truth

from analyzing video

- *distance* trace
- *visibility-distance* trace

Distance d1 @ t= to

Distance changed to d' @ t= t'

Algorithm outputs

LED is in error if

- Not resolvable due to change in distance (*mode*)
- It is occluded

Partial Visibility (partial occulsion)

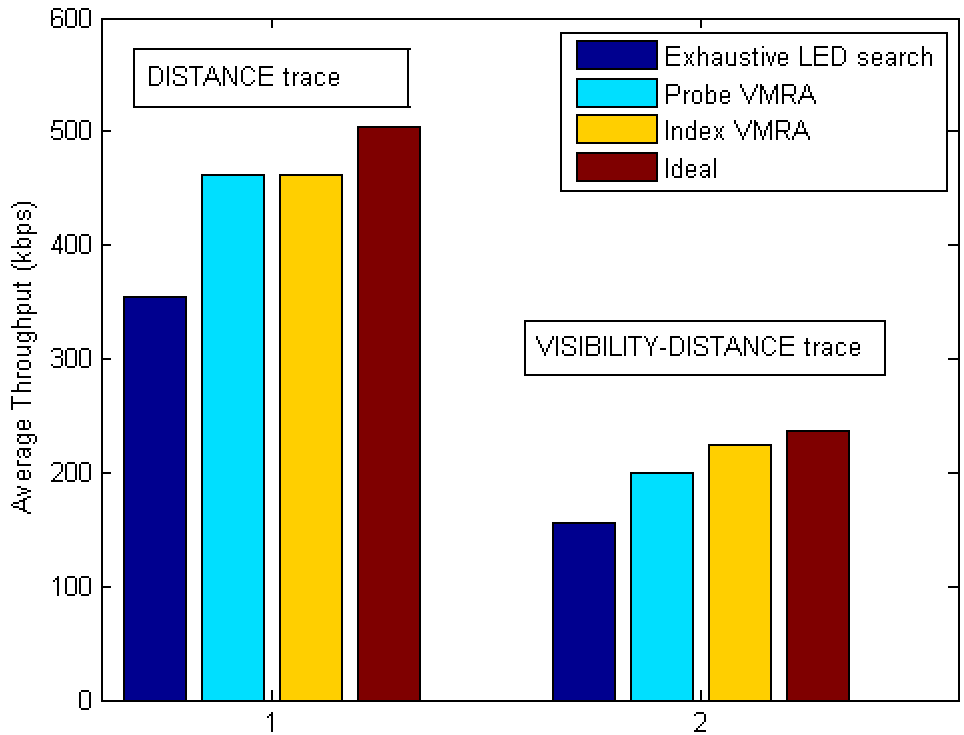
No visibility (Complete Occlusion)

Results

- average throughput

$$\rho = \frac{1}{B/T} \sum_{i}^{(B/T)} Rate(i)(1 - error(i))$$

B = averaging time window
T = adaptation time window (10/60 sec)



Ideal is an oracle solution where the system exactly knows what *mode* to choose and what LEDs to operate with

Conclusion

- Adapt Visual MIMO data rate to optical channel distortions
  - Visibility
  - Blur
  - Perspective effects
- Possible solutions & Challenges
  - Exhaustive Visibility search : inefficient
  - Probe VMRA : requires 'smart' spatial patterning
  - Index VMRA : framing packets and LED assignments
- Future Work: Addressing weather conditions, Skew in image

THANK YOU ☺

Questions?

aashok@winlab.rutgers.edu