Unit - 4

Motivation

- There were nearly 6,420,000 auto accidents in the United States in 2005
- The financial cost of these crashes was more than 230 billion dollars
- 6858 people were injured in road accidents in 2006
- 60% of collisions could be avoided given at least 0.5 sec warning

Motivating Example

Scenario: *A*, *B*, and *C* traveling in same direction. *A* suddenly brakes.

Being farther from *A* does not make *C* ***safer*** for 2 reasons:

- Line of sight limitation
- Large human processing/forwarding delay (reaction time)

Can we build a quicker warning system using vehicle-to-vehicle (V2V) communication?

Cooperative Collision Warning

Scenario: *A*, *B*, and *C* traveling in same direction. *A* suddenly brakes.

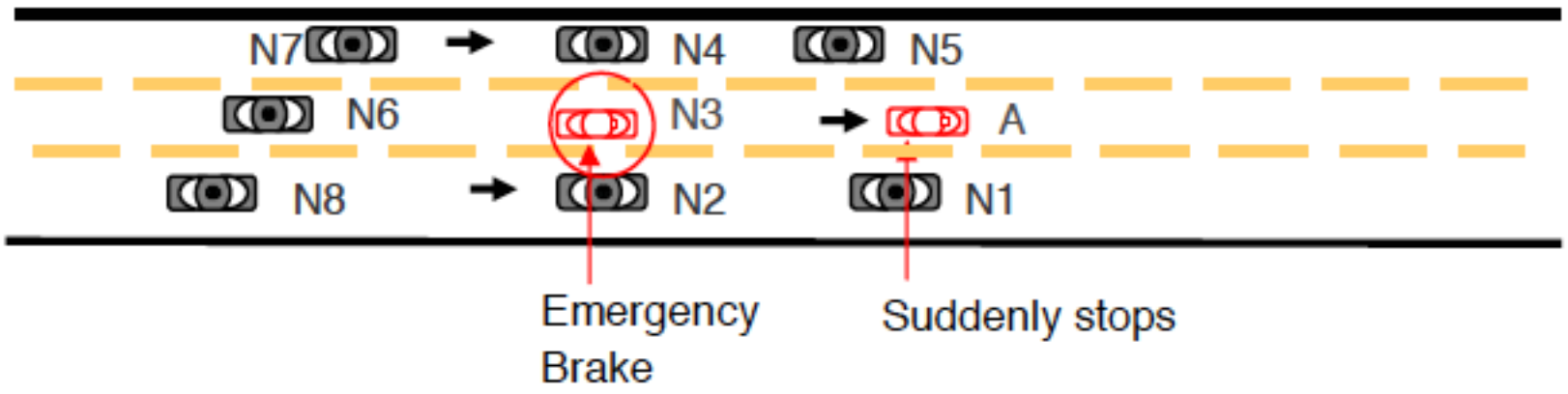
Using V2V the danger for all parties is alleviated:

- *A* can send warning messages immediately once emergency is detected
- Assuming little delay, *B* and *C* can receive the alerts and react

Challenges

1) Stringent delay requirement (in the order of ms)

- A vehicle traveling 80mph covers > 1m per second
- Several obstacles:
  - Doppler shifts from high mobility
  - Packet collision rate
  - Large churn in the pool of endangered vehicles



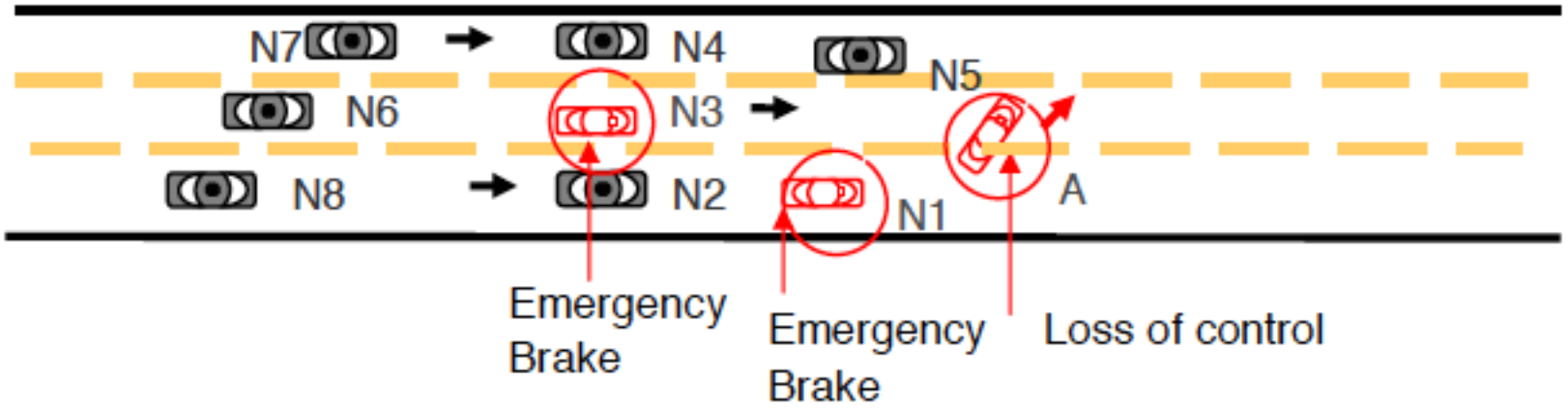
Challenges (cont'd)

2) Support for multiple co-existing vehicles over long period

- Emergencies may take hours to clear
- By nature, road emergencies have chain reaction

3) Differentiation of emergency events and redundant messages

- Vehicle trajectory helps differentiate emergency events
- Redundant messages can overload the communication channel

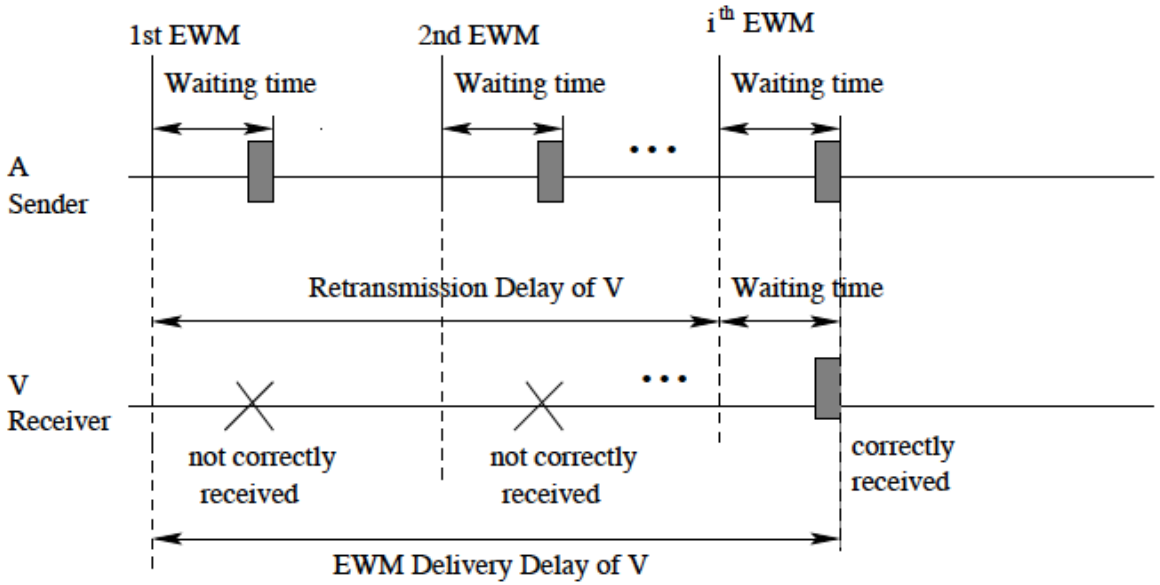


Vehicle Collision Warning Communication (VCWC) Protocol

- Definitions and abbreviations:
  - Abnormal Vehicle (AV)
  - Emergency Warning Message (EWM)
    - Geographical location
    - Speed
    - Acceleration
    - Moving direction
- Assumptions about participating vehicles:
    - Capable of determining geographic location relative to road (GPS)
    - Must be equipped with at least one wireless transceiver
    - Transmission range is assumed to be 300m (Dedicated Short Range Communications (DSRC) consortium suggestion)

Congestion Control

- **Goal:** achieve low EWM delivery delay at time of emergency while scaling to many co-existing AV's
  - EWM delivery delay from *A* to *V* – elapsed duration from time of emergency event at *A* until message received by *V*
  - Delay = $\text{Delay}_{\text{wait}} + \text{Delay}_{\text{transmission}}$



Congestion Control (cont'd)

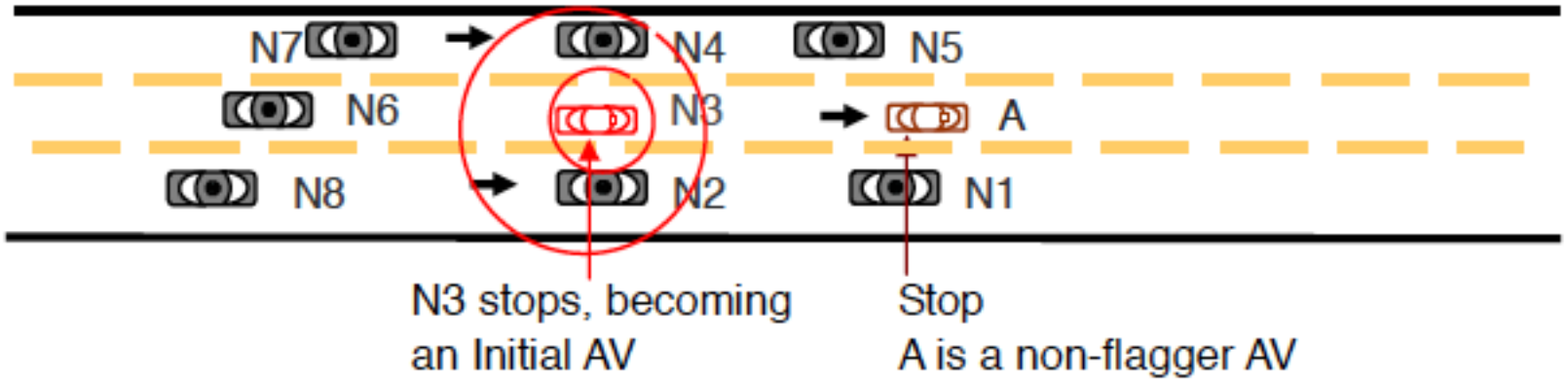
- Congestion traditionally regulated via transmission success rate
  - Will ***not*** work in multicast scenario
- VCWC uses multiplicative transmission rate decreasing
  - Transmission ra $f(\lambda_0, k) = max\left(\lambda_{min}, \frac{\lambda_0}{a^{\lfloor \frac{k}{L} \rfloor}}\right)$ fter every L transmissions
  - $a = 2$ and $L = 5$ determined empirically

State Transitions of AVs

- **Goal:** Ensure maximal message dissemination while eliminating redundant messages clogging the network
- AV can be in three states:
  - Initial AV – transmits at initial rate, λ_0, and decreases using multiplicative decrease
  - Flagger AV – transmits at minimal rate λ_{min}
  - Non-flagger AV – does not transmit

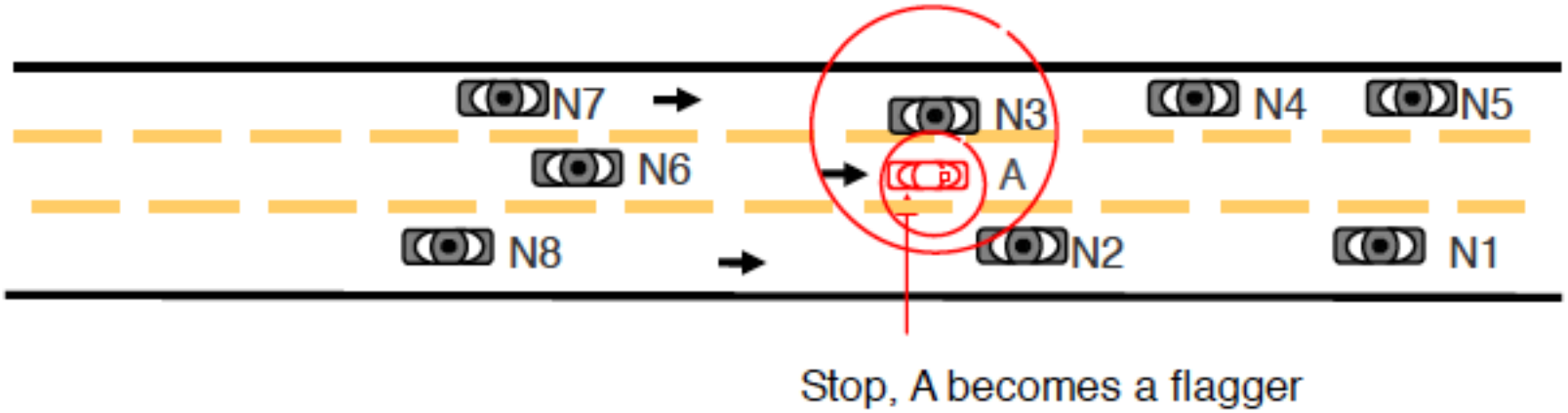
State Transitions of AVs (cont'd)

- Transition from initial AV to non-flagger if *both*:
  - At least T_{alert} time passed since entering initial AV state
  - EWM's from at least one *follower* is overheard
    - X is follower of Y if X located in lane behind Y and all vehicles endangered by Y are endangered by X



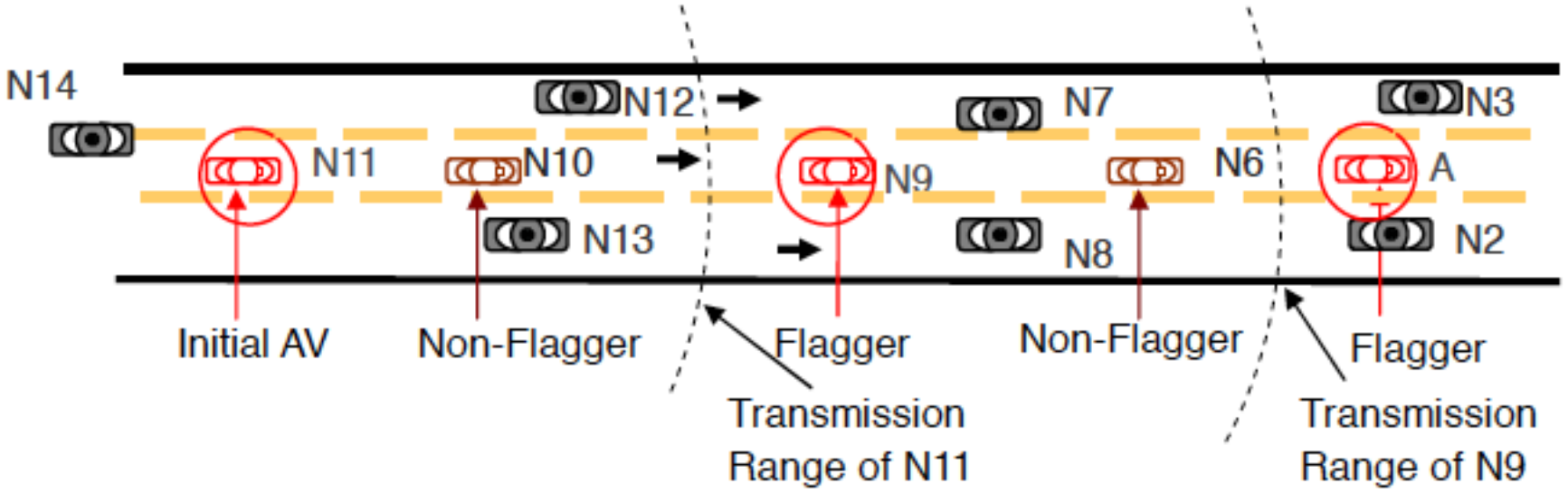
State Transitions of AVs (cont'd)

- Transition from non-flagger AV to flagger if *both*:
  - Become flagger if EWMs are not received by followers after flagger timeout (FT)
  - Otherwise reset FT, repeat



AV Transitions and interactions

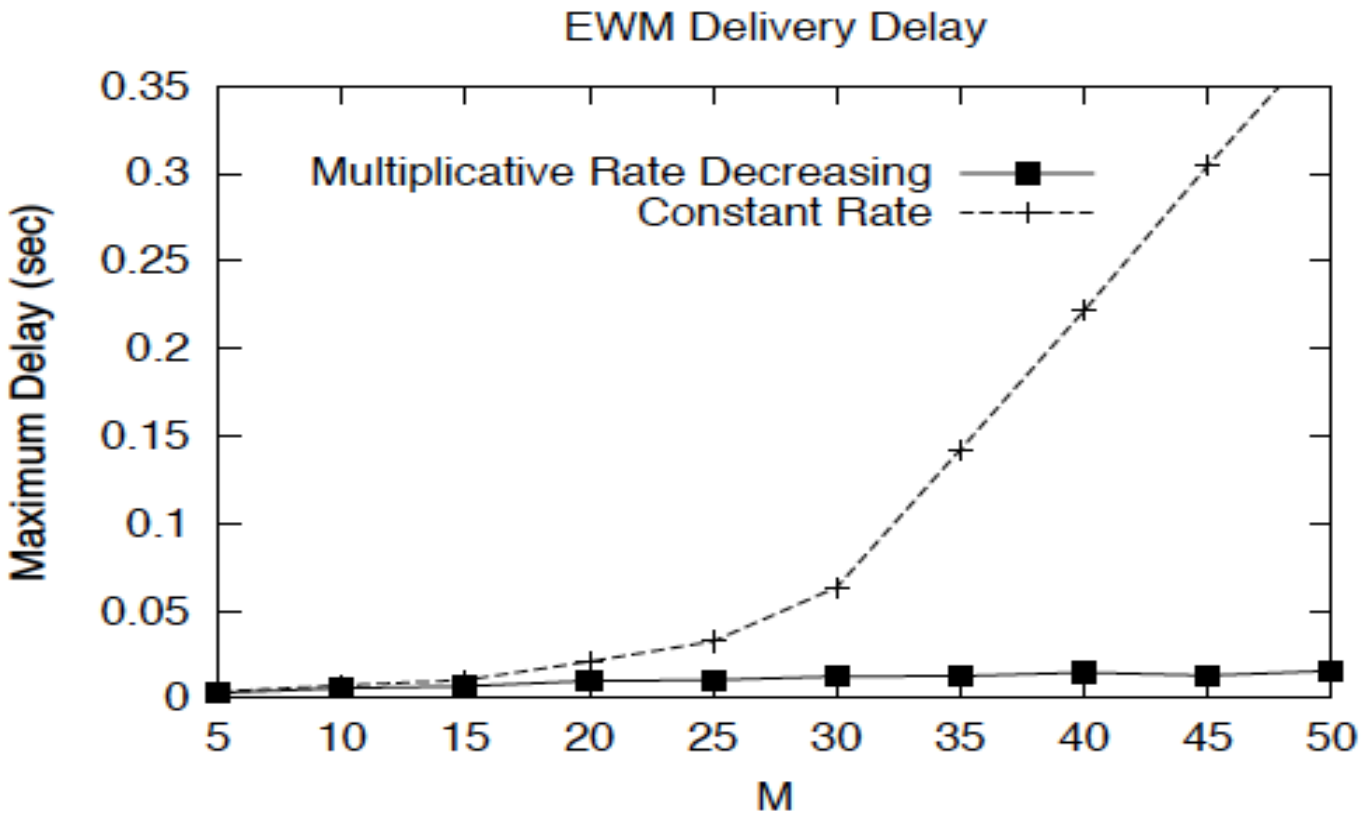
- Last AV in a "pile up" is always an initial AV



Performance Evaluation

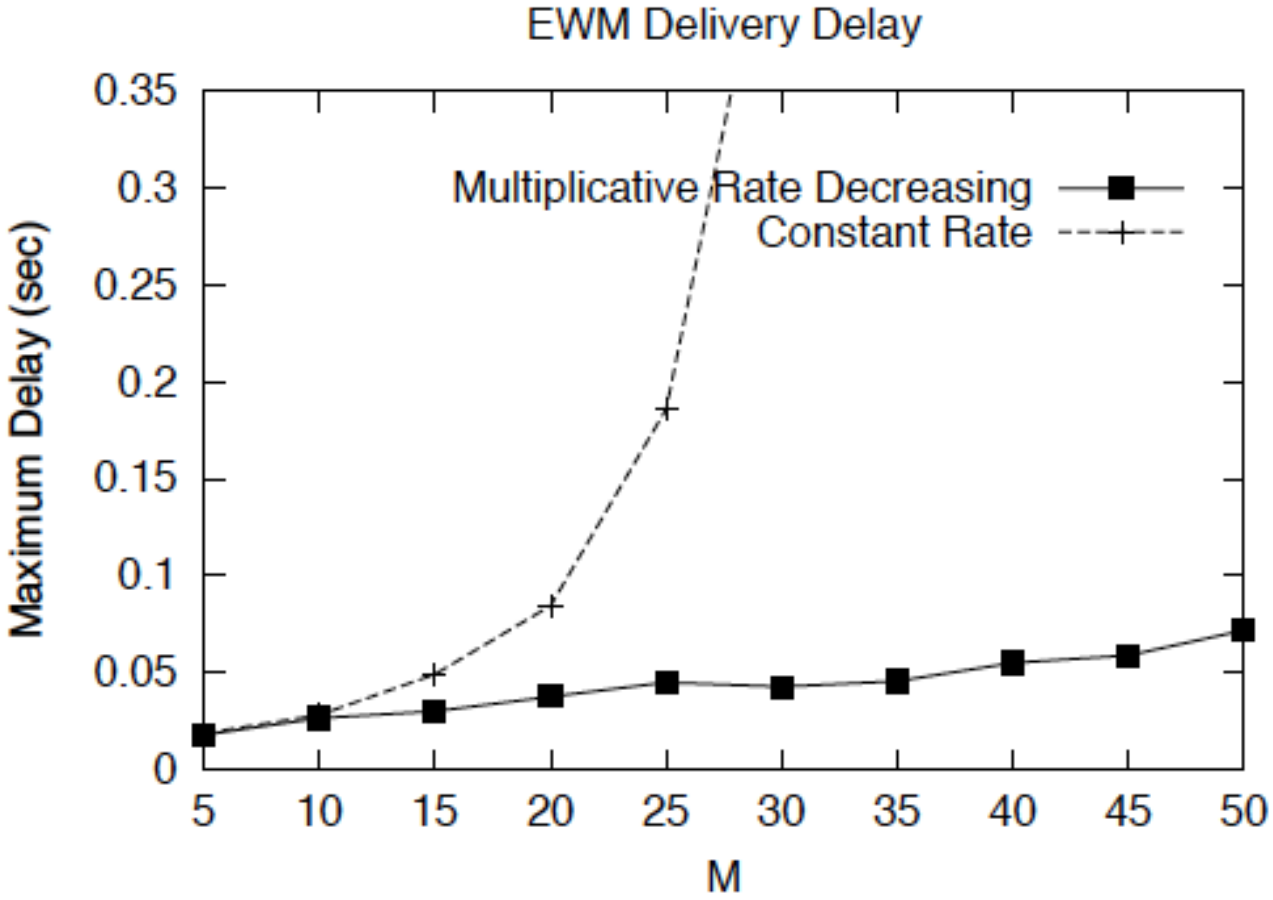
- Simulation implemented in ns-2 simulator
- $Delay_{wait}$ and $Delay_{transmission}$ modeled as Poisson distribution
- Simulation parameters:
  - $\lambda_0 = 100$ msg/sec
  - $\lambda_{min} = 10$ msg/sec
  - FT = 0.5 sec
  - $T_{alert} = 450$ ms
  - L = 5
  - $a = 2$

Performance Evaluation



- Good channel condition (p = 0.9)
- Rapid increase in delay for constant rate after M~25

Performance Evaluation



- Good channel condition (p = 0.5)
- Rapid increase in delay for constant rate after M~15