Video Multicast over WLAN

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Outline:

- Motivation and Problem Statement
- More about the problem
- Description of OPNET wlan model
- Modifications made in the OPNET model
- Future work
- References

Motivation and Problem Statement:

- WLAN technologies are being increasingly used for multimedia transmissions.
- Video streaming is very different from data communication due to inherent delay constraints.
- Video streaming applications have not been studied extensively for IEEE 802.11 based networks.
- How MAC layer multicast and error control techniques can improve service quality and/or capacity.

Challenges for video streaming over WLANs:

Wireless video transmission is a challenging task because of the following factors:

- limited bandwidth
- high bit errors compared to wired links
- time-varying error–prone environment
- receiver heterogeneity

How to meet the challenges?

- FEC: transmit additional redundant packets that can be used at the receiver to reconstruct lost packets.
- ARQ: the sender retransmits the packets that have not been received correctly at the receiver.
- Hybrid ARQ: another option

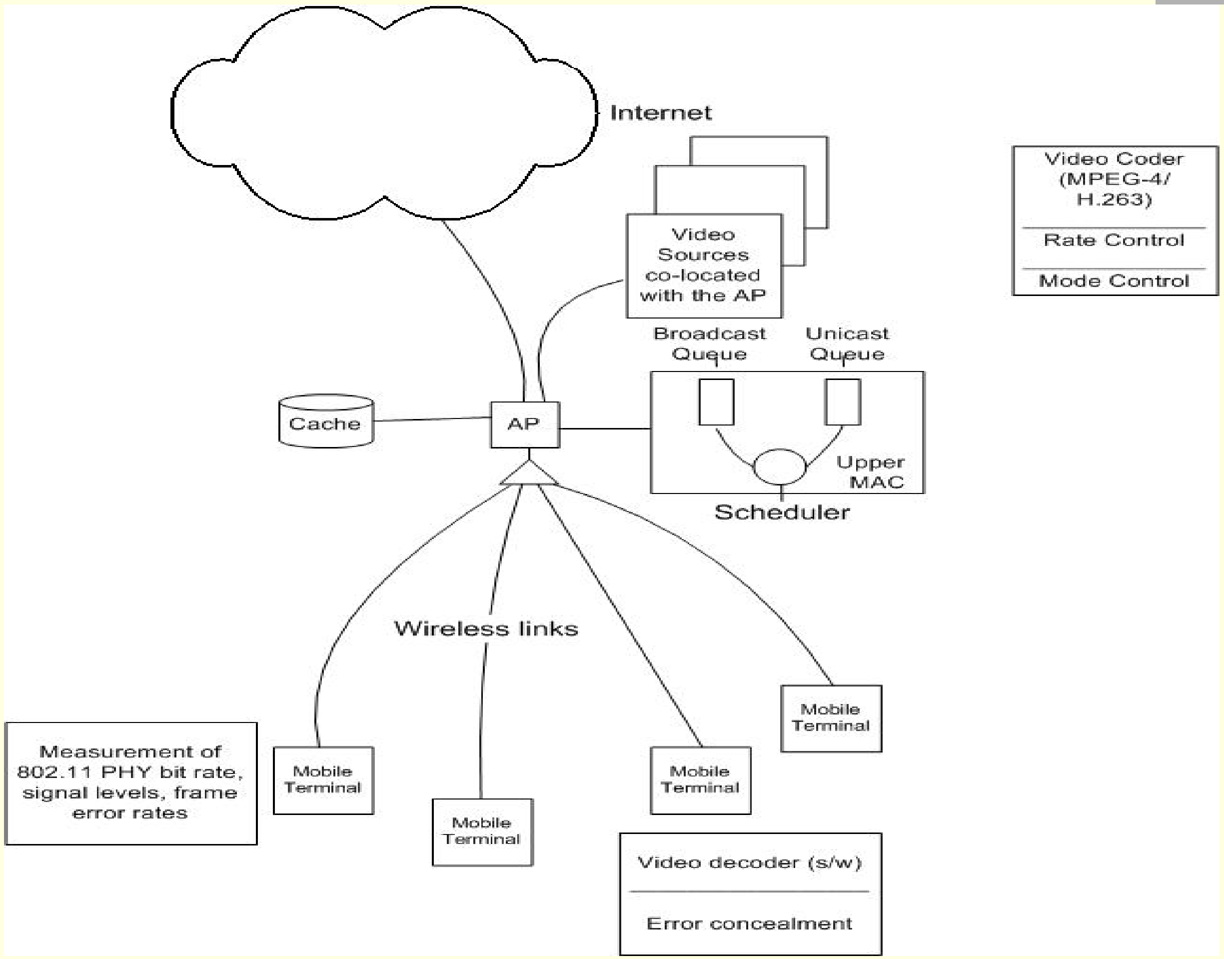
How to deal with receiver heterogeneity

- Simulcasting the content at different rates. Video server will multicast monolithic video streams at different rates and mobile terminals would subscribe to multicast groups according to their bandwidth estimations.
- Layered coding: basis of Receiver Driven Layered Multicast scheme.

System Model

- Video server co-located with AP.
- N Mobile Terminals [MTs].
- Multi-resolution streams of MPEG video are available from the server.
- Each MT will report its PHY bit-rate, signal strength and packet error rates periodically to the AP.
- The feedback controller at AP will receive feedback from MTs and congestion status from MAC and decide on the multicast groupings.

Network Architecture



System Model (Contd.)

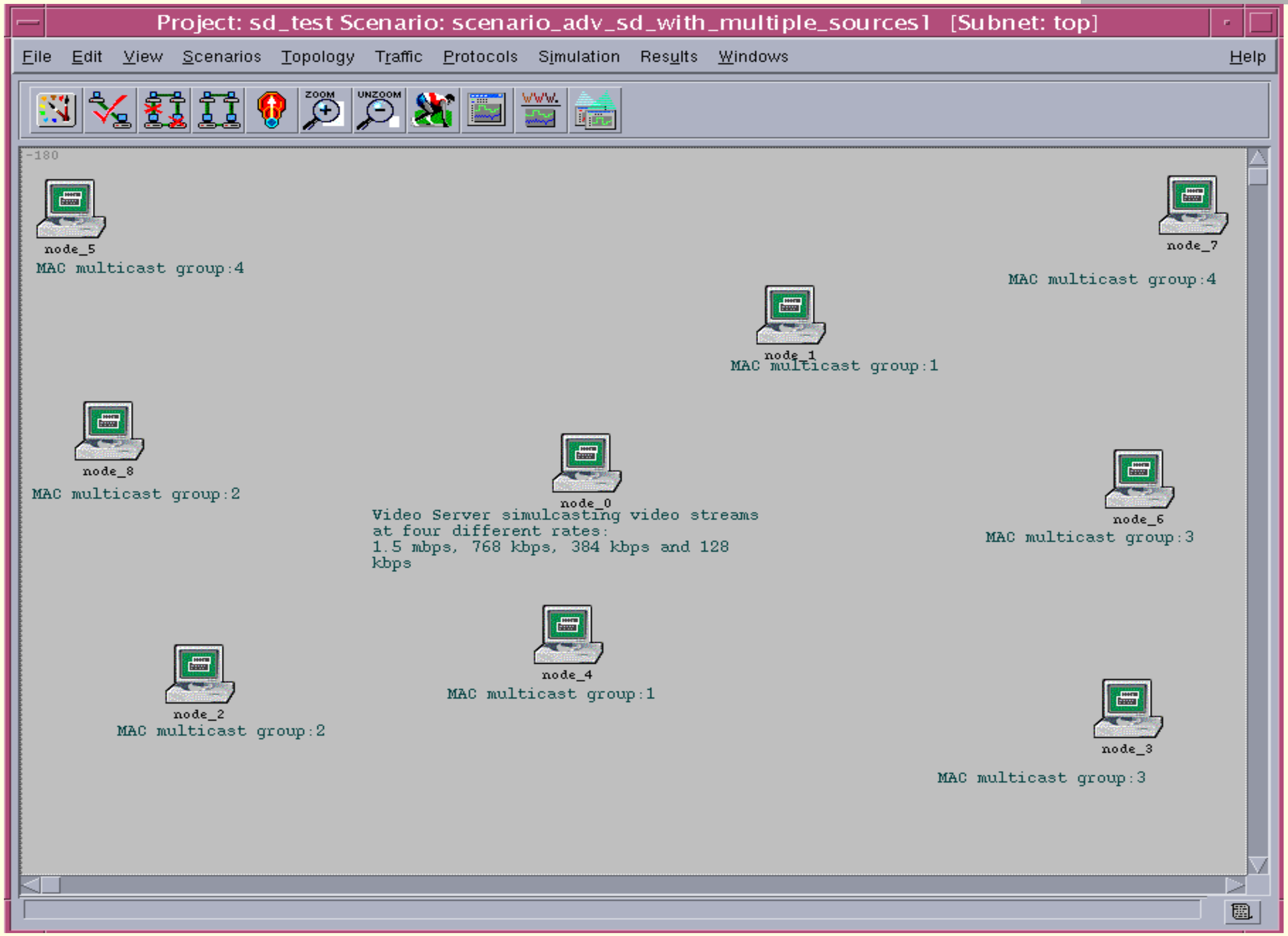
Multicast Groupings:

- the bit-rates of the video streams for the different multicast groups.
- which MTs are assigned to which multicast group.
- the type/percentage of FEC to be used for each stream being transmitted.
- the type/percentage of ARQ (if any) to be used for each stream being transmitted.
- the optimum feedback rate by MTs.

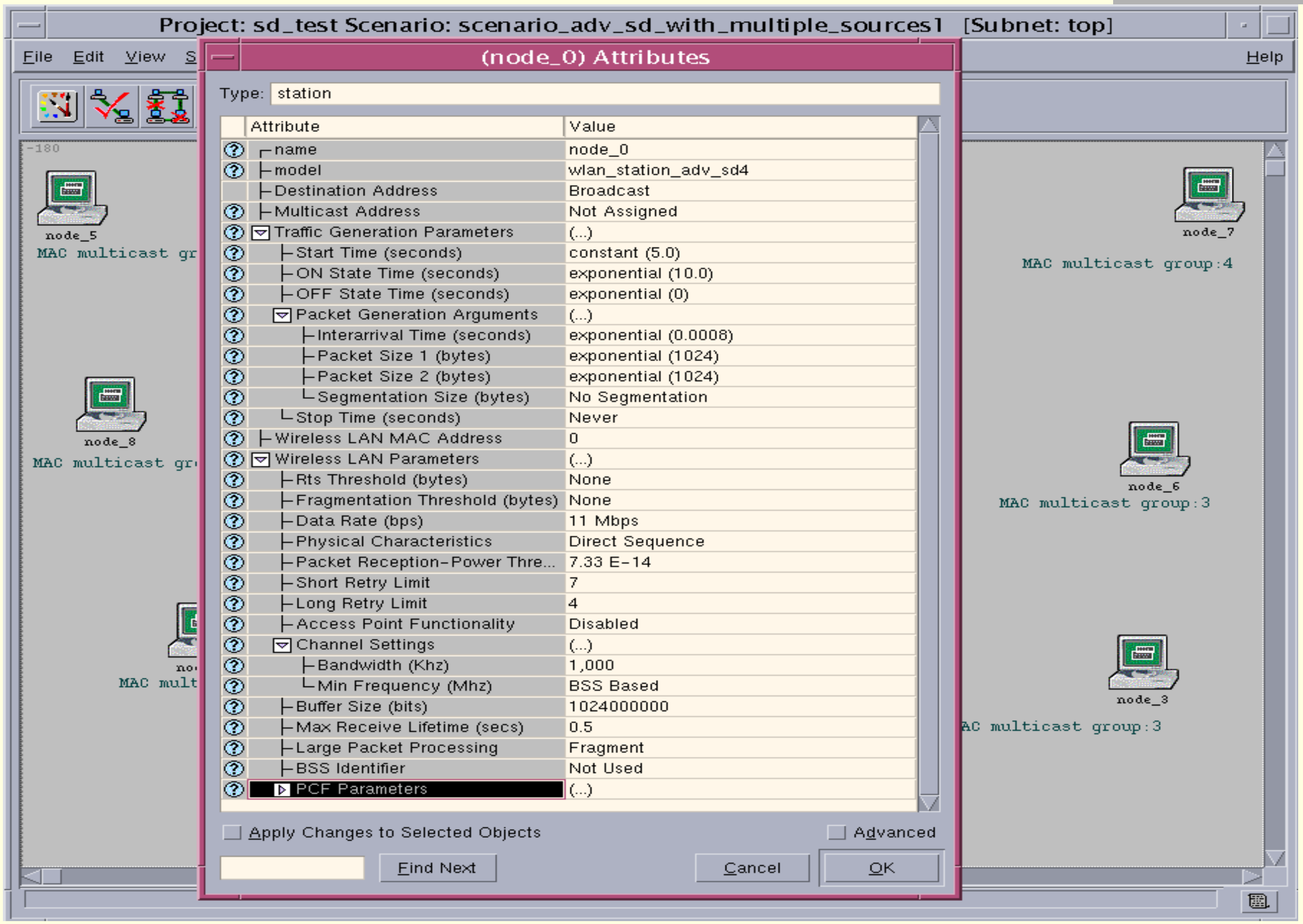
OPNET Modeler:

- OPNET is a network simulation tool
- Graphical specification of network models
- Event driven simulation kernel
- Integrated data analysis tools
- Object based modeling with hierarchy
- Modeler: Tool which provides environment for modeling and simulation of communication systems, protocols and networks.

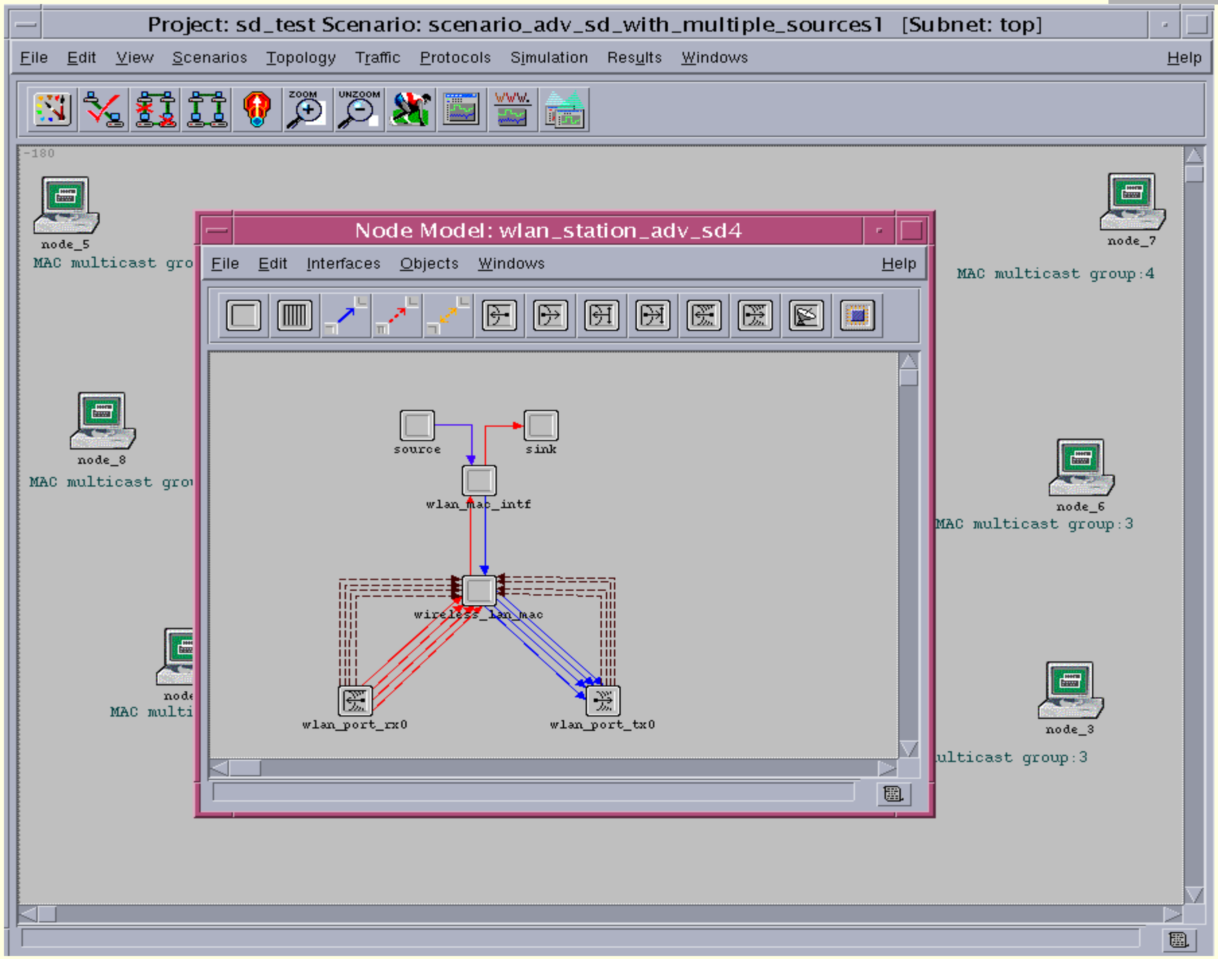
OPNET Simulation Model



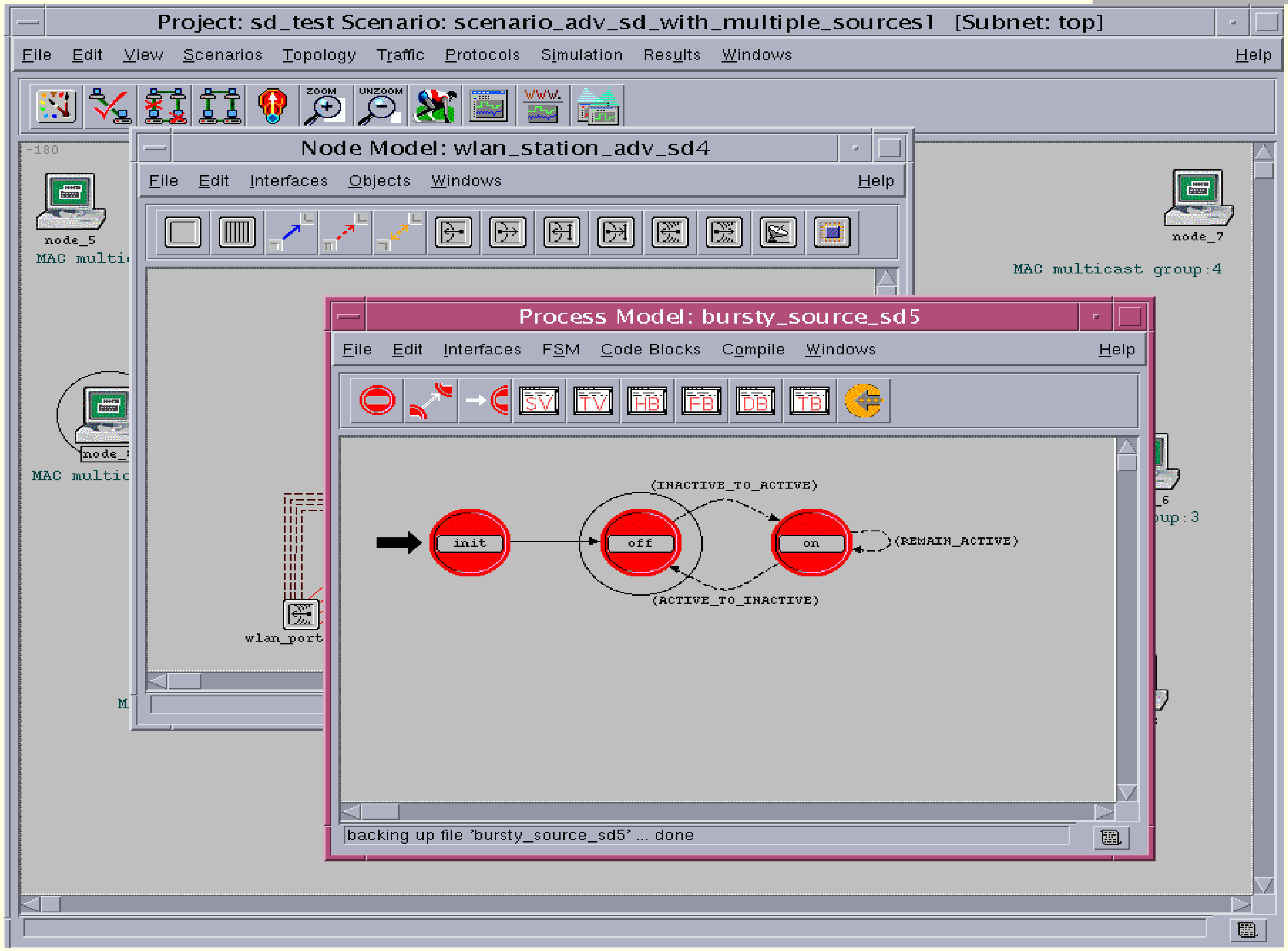
WLAN Node Attributes



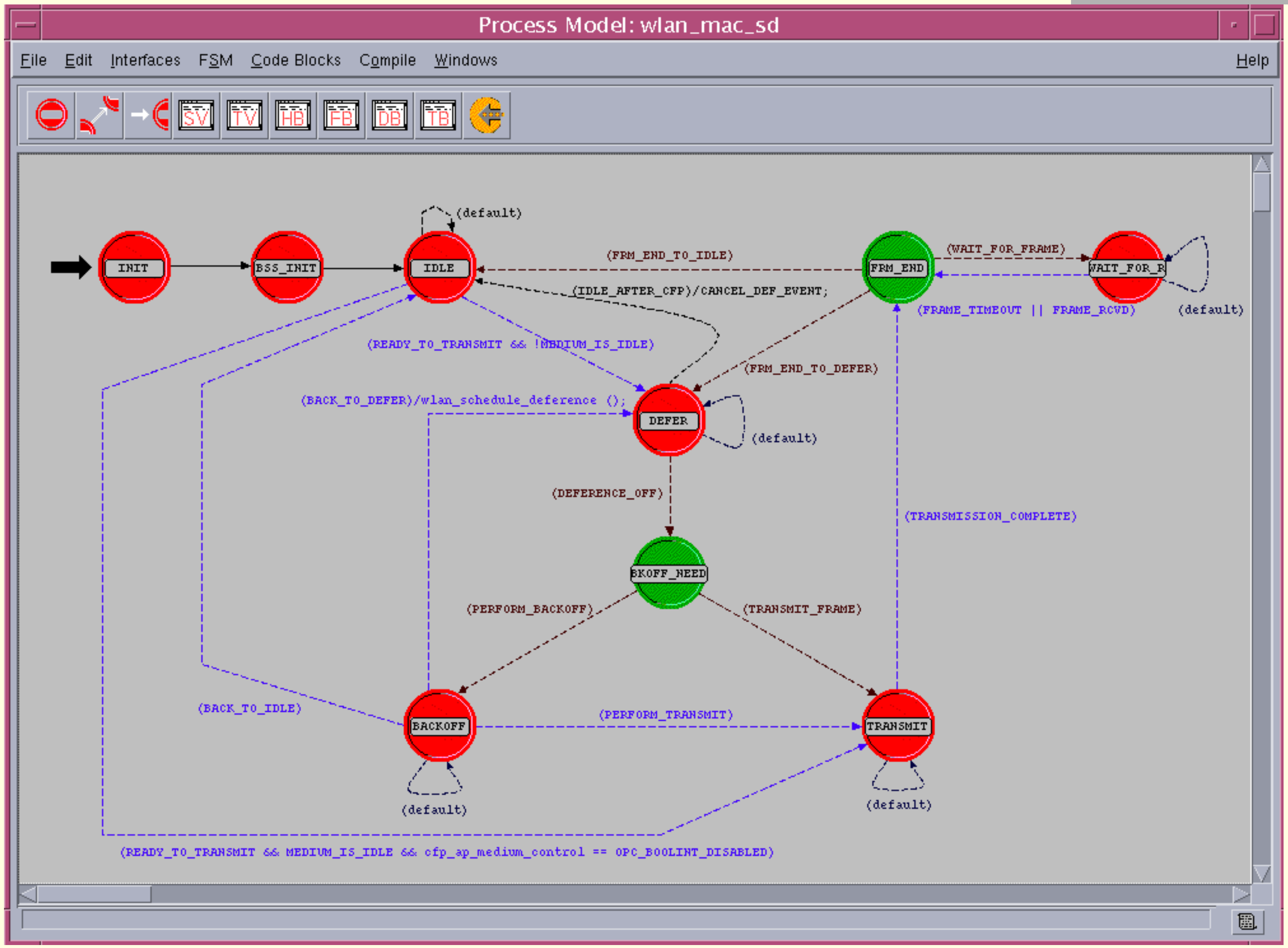
WLAN Node Model



Bursty Source Process Model



MAC Process Model



Modifications Done in OPNET Model:

- Modified Bursty Source Process Model generates multiple traffic for multiple destinations.
- Modified MAC process model can handle MAC multicast.
- Modification made in the OPNET radio pipeline stage for allocating errors in transmitted packets that takes care of the special characteristics of the wireless channel.

Modifications Done (Contd.):

Bursty Source Process Model:

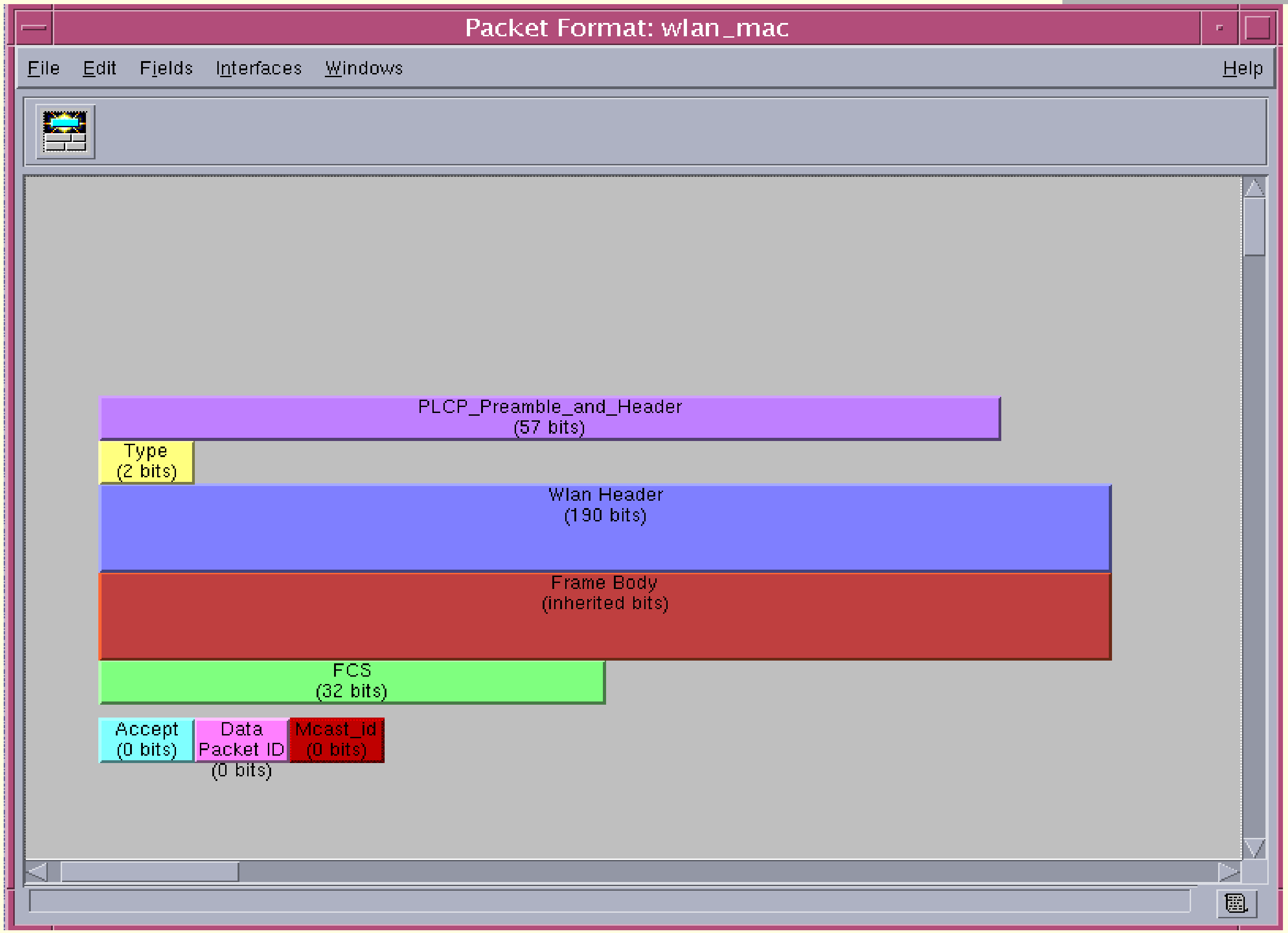
- Generation of four video streams at the following bit-rates: 1.5 Mbps,768 kbps,384 kbps and 128 kbps.
- This translates to generating packets/frames according to four distributions every 33ms (transmitting 30 frames/sec).
- Modified Bursty Source Process Model generates packets according to multiple distributions (with the same interarrival time) for different multicast groups.

Modifications Done (Contd.):

MAC Interface and MAC:

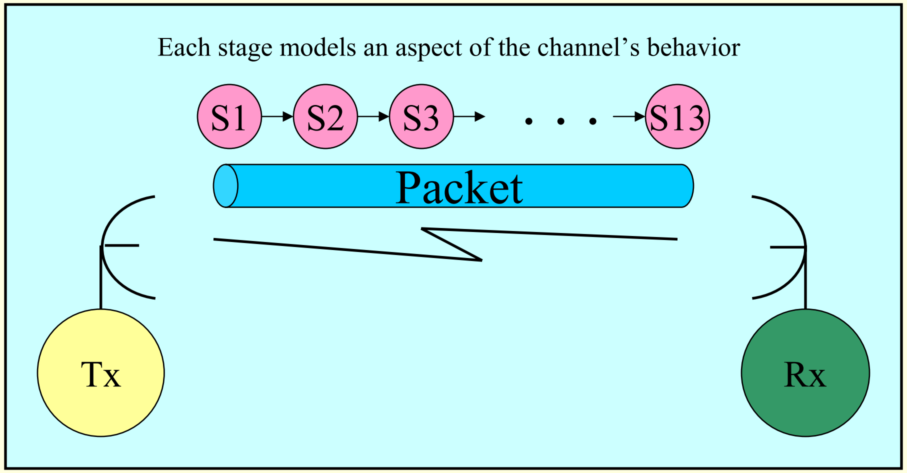
- Modified MAC Interface process model can handle packets for multiple destinations from the source process model.
- Modified MAC process model can handle packets generated for multicast groups in addition to unicast/broadcast packets.
- Demultiplexer functionality implemented in MAC process model so that it will send to higher layers the packets which are generated for the multicast group to which the associated node has subscribed to.

Modified Packet Format:

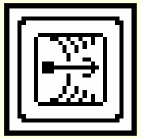


OPNET Transceiver Pipeline

- Models packet transmission across communication channel
- Implements physical-layer characteristics
- Determines if a packet can be received



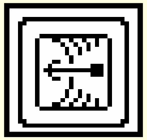
Radio Pipeline Model Attributes



Radio Transmitter

- Receiver Group
- Transmission Delay
- Link Closure
- Channel Match
- Tx Antenna Gain
- Propagation Delay

6 stages (0-5) associated with Radio Transmitter

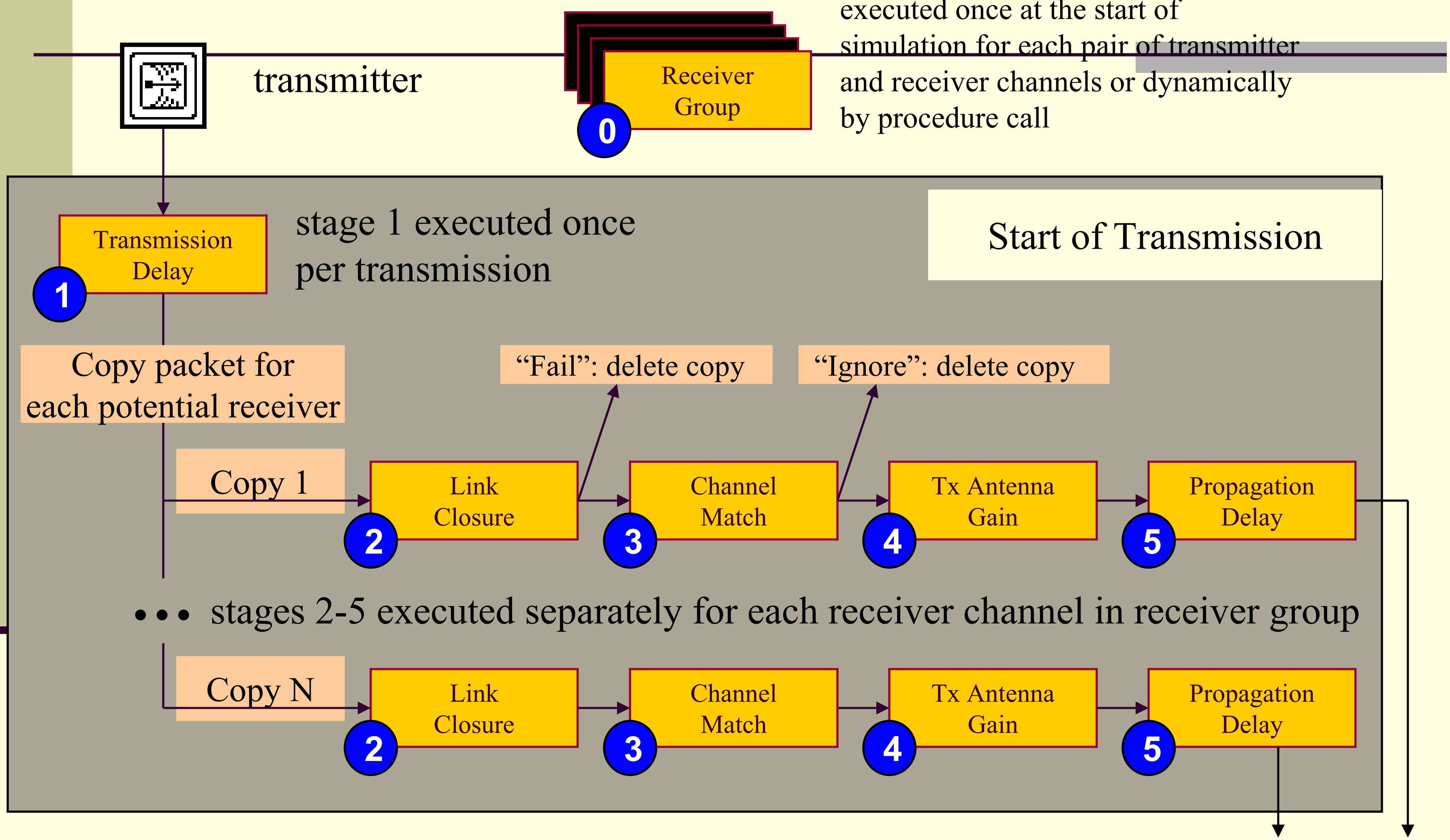


Radio Receiver

- Rx Antenna Gain
- Received Power
- Background Noise
- Interference Noise
- Signal-to-Noise Ratio
- Bit Error Rate
- Error Allocation
- Error Correction

8 stages (6-13) associated with Radio Receiver

Radio Pipeline Stages (Transmitter Side)



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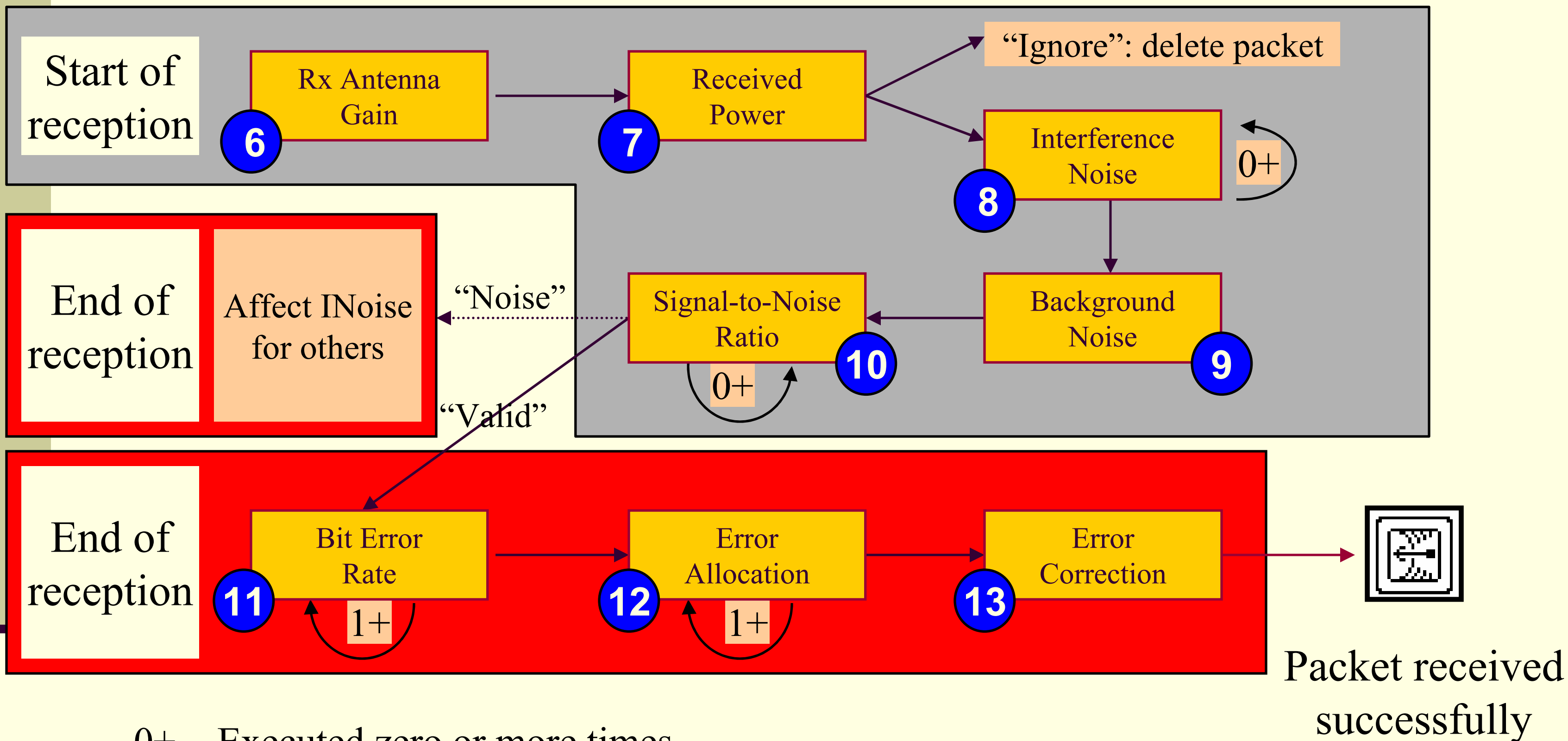
Radio Pipeline Stages (Receiver Side)



0+ Executed zero or more times

1+ Executed one or more times

Pipeline Stage 12: Error Allocation (default)

- Does not perform bit-by-bit error computations
- Cannot retain bit-error location
- Computes probability of k errors
- Generates uniform random number: r = (0 1]
- Integrates probability mass over possible outcomes

$$P_k = p^k (1-p)^{N-k} \binom{N}{k}$$

$$\sum_{k=0}^{N} P_k \geq r$$

P_k = Probability of k Errors

p = Probability of Error

N = Packet Length (bits)

$r = op\_dist\_uniform(1)$

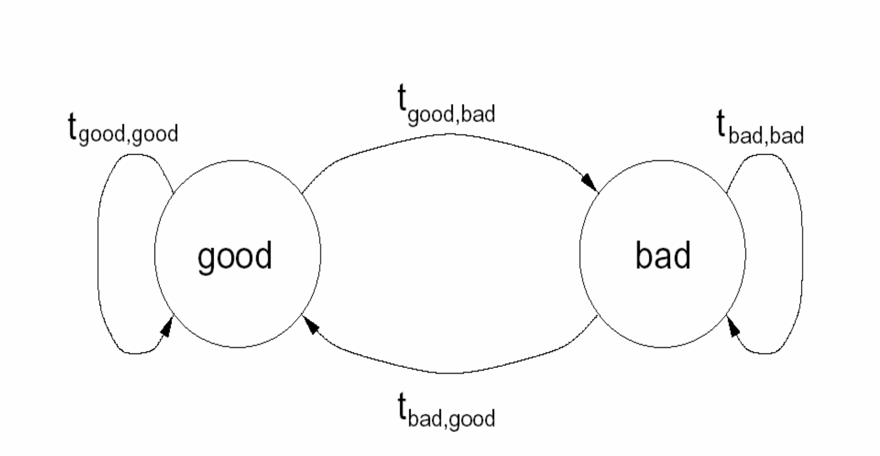
k = Number of Errors

Pipeline Stage 12: Error Allocation (contd.)

- OPNET uses the same error allocation model for allocating errors in point-to-point and bus links.
- Loss characteristics of wireless channels are bursty due to various fading effects. OPNET wlan model does not take into account the special characteristics of the wireless channel.

Modifications in Pipeline Stage 12:

- Gilbert-Elliott model is a DTMC with two states: “good” (G) and “bad” (B).
- In good state losses occur with low probability while in “bad” state losses occur with high probability.



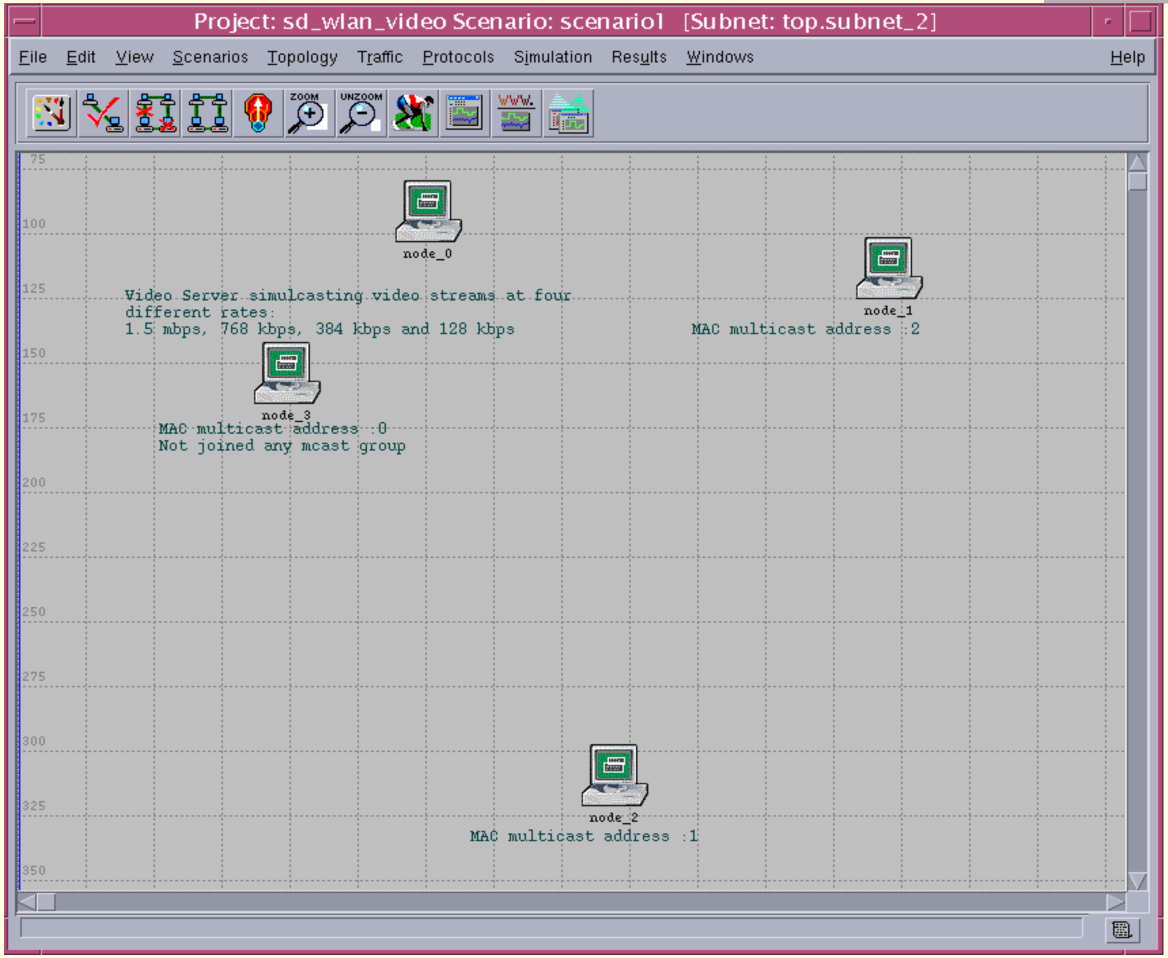
Gilbert Model: Probabilities of good and bad states

- Probability of being in good state is
  pG = pBG/(pBG + pGB)

- Similarly, probability of being in bad state is
  pB = pGB/(pBG + pGB)

- The transition probabilities pGB and pBG are related to the average error-free length LG and error length LB by the following relations
  pBG = 1/LB
  pGB = 1/LG

Simulation Result of MAC Multicast

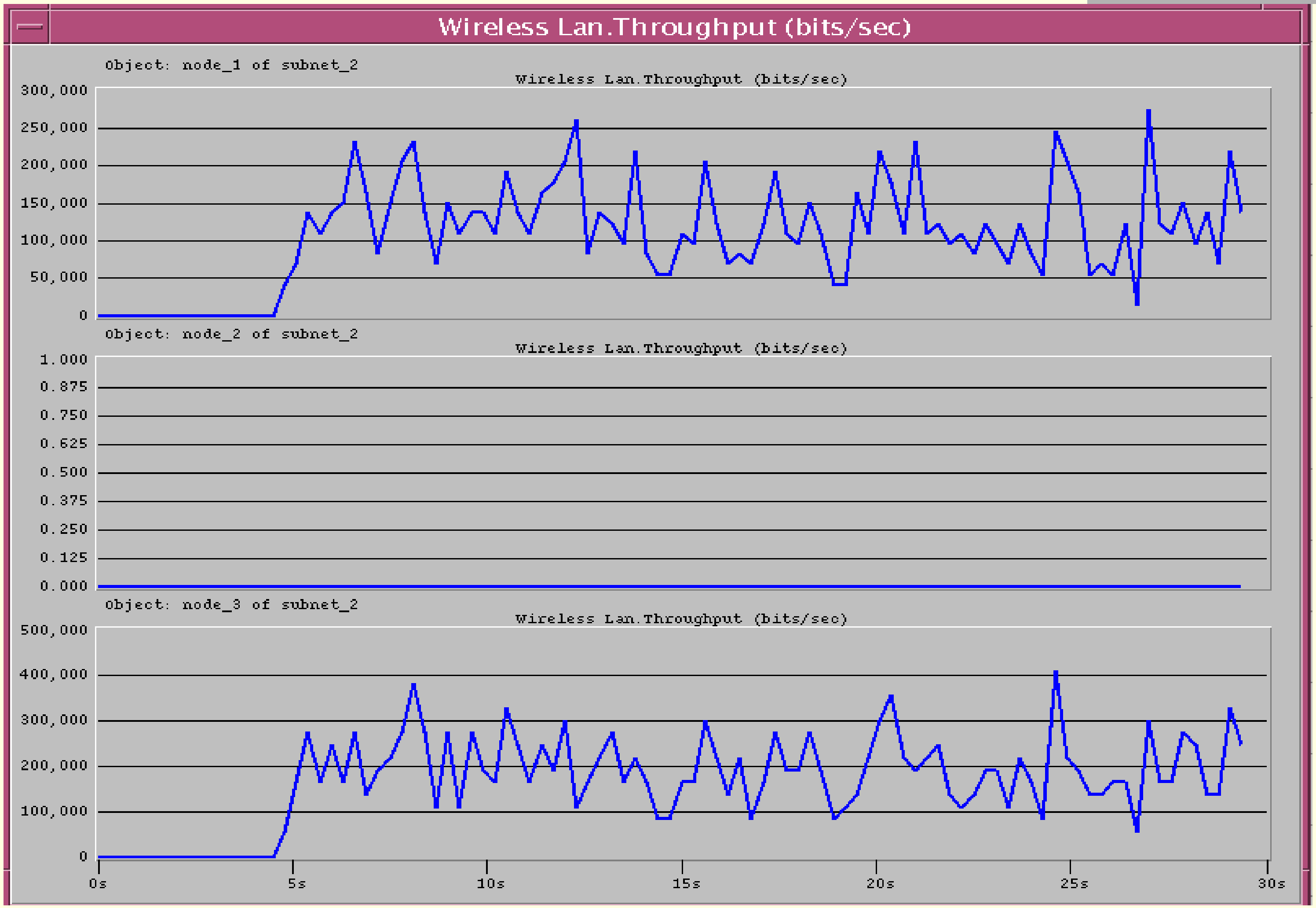


Simulation Result of MAC Multicast (Contd.)

- Stream 1 : Packet Size-constant 1024 bytes (multicast group 1)
- Stream 2 : Packet Size-constant 512 bytes (multicast group 2)

- Node 0: AP (transmitting two streams)
- Node 1: subscribed to multicast group 2
- Node 2: not subscribed to any group
- Node 3: subscribed to multicast group 1

Simulation Result of MAC Multicast (Contd.)



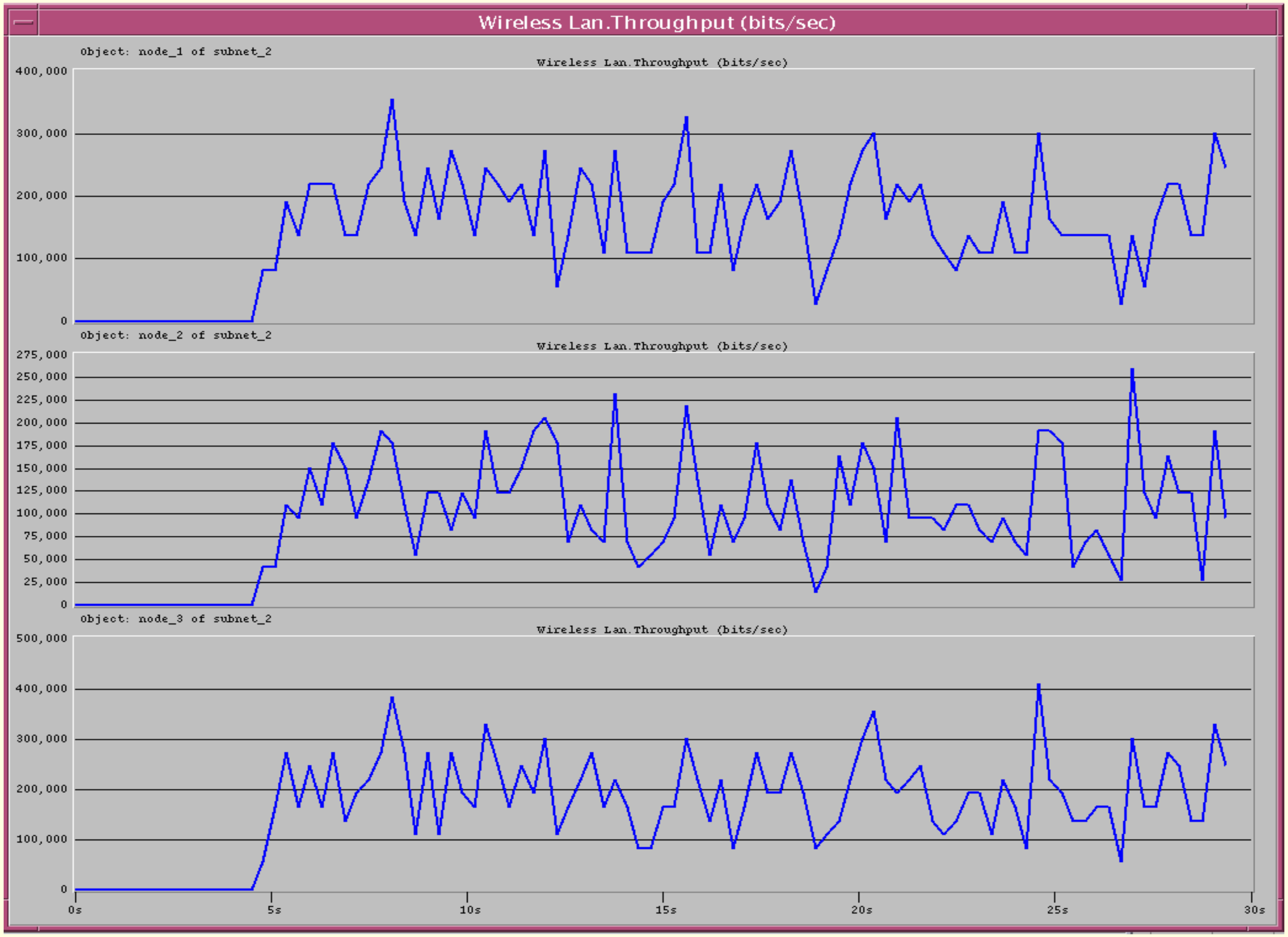
Simulation Result of MAC Multicast (Contd.)

- Stream 1 : Packet Size-constant 1024 bytes (multicast group 1)
- Stream 2 : Packet Size-constant 512 bytes (multicast group 2)

- Node 0: AP (transmitting two streams)
- Node 1: now subscribes to multicast group 1
- Node 2: now subscribes to multicast group 2
- Node 3: still subscribed to multicast group 1

Observe that average throughput doubles for Node 1

Simulation Result of MAC Multicast (Contd.)



Selection of multicast group

Mobile receivers are measuring the following things

- BER of a packet for its multicast group
- Short-term BER
- Long-term BER

Receivers join/leave multicast groups according to the above measurements.

Selection of multicast group (Contd.)

```
In MAC higher layer data arrival, dest. mcast group of pkt is 1

In MAC higher layer data arrival, dest. mcast group of pkt is 2

In MAC physical layer data arrival: mcast group of pkt is 1
In MAC physical layer data arrival: mcast address of receiver is 1
HOLA My packet has arrived
ACTUAL (current) BER value= 0.000000
op_sim_time()=29.935230
Next timer time=36.167140
Pkt counter =18
Running Average BER =0.001091
AVERAGE BER= 0.000746
Mcast group matches and THROUGHPUT WRITTEN
Sending data to higher layer through mac interface

In MAC physical layer data arrival: mcast group of pkt is 1
In MAC physical layer data arrival: mcast address of receiver is 2
No further calculation of BER


In MAC physical layer data arrival: mcast group of pkt is 1
In MAC physical layer data arrival: mcast address of receiver is 0
No further calculation of BER


In MAC physical layer data arrival: mcast group of pkt is 2
In MAC physical layer data arrival: mcast address of receiver is 1
No further calculation of BER

In MAC physical layer data arrival: mcast group of pkt is 2
In MAC physical layer data arrival: mcast address of receiver is 2
HOLA My packet has arrived
ACTUAL (current) BER value= 0.000000
op_sim_time()=29.936620
Next timer time=36.168651
Pkt counter =18
Running Average BER =0.001111
AVERAGE BER= 0.000000
Mcast group matches and THROUGHPUT WRITTEN
Sending data to higher layer through mac interface

In MAC physical layer data arrival: mcast group of pkt is 2
In MAC physical layer data arrival: mcast address of receiver is 0
No further calculation of BER
```

Future Work

- Receivers joining and leaving multicast groups on the basis of measurements of BER so that each receiver receives best possible quality of video.
- Simulations with FEC/ARQ
- Receivers providing feedback to AP which in turn decides on the multicast groupings (as opposed to receiver driven approach)

References

- OPNET Modeler: www.opnet.com
- References of papers relevant to this work can be found in my project webpage http://www.winlab.rutgers.edu/~soumya/research.htm