Efficient, Fault-Tolerant All-Optical Multicast Networks
via Network Coding
R. C. Menendez and J. W. Gannett

Network Coding: Network nodes perform logical operations, not just signal repetition.

Photonic Bitwise Exclusive-OR (XOR)

Generalizations

Nodes N and S Protect Each Other
6 Tx/Rx Pairs vs. 8 Conventional
25% Savings

Nodes N and S Protect 3rd Broadcast (C)
8 Tx/Rx Pairs vs. 12 Conventional
33% Savings

Node S Protects Another Node (C)
9 Tx/Rx Pairs vs. 12 Conventional
25% Savings

Conventional: 10 Tx/Rx Pairs
Network Coding: 8 Tx/Rx Pairs
20% Savings

Signal Recovery at N after Link Failure

Recover Lost Signal From E:
\[ E = W \oplus (W \oplus E) \]

Electronic or Photonic XOR; Latency Compensation Required

Network Coding

Markov Analysis: Unavailability of one multicast signal at either node with other signal in service

Markov Analysis: Unavailability of one multicast signal at either node

\[ F = \frac{1}{5} \left( \frac{1}{3} + \frac{1}{3} + \frac{1}{3} + \frac{1}{3} + 1 \right) \]

Fiber link failures dominate Tx/Rx failures.

\[ = 400 \text{FIT/mile, and mean-time-to-repair (MTTR) of 5.6 hours.} \]

\[ \text{mean-time-to-failure (MTTF)} = 200 \text{km length each, unavailability of one multicast signal at either node with other signal in service} \]

\[ \text{unavailability of one multicast signal at either node} \]

\[ \text{XOR failure rate} \]

\[ \text{link failure rate} \]

\[ \text{repair rate} \]

\[ \text{working state} \]

\[ \text{failed state} \]

\[ \text{unprotected} \]

\[ \text{protected} \]