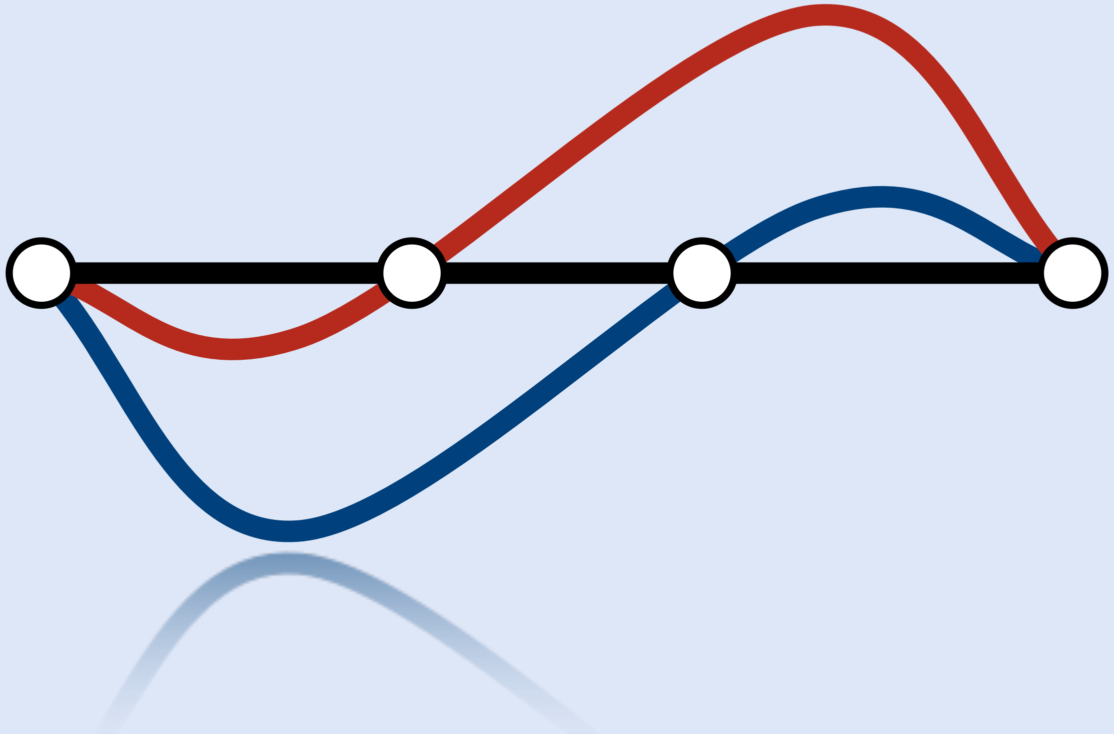
Analyzing Channel Assignment with Rearrangement in Multi-Channel Wireless Line Networks



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Wireless infrastructure networks

Wireless infrastructure networks becoming more popular

- Backbone may operate in 802.11a, while user interface may be on 802.11b/g

Increasing throughput in wireless infrastructure networks

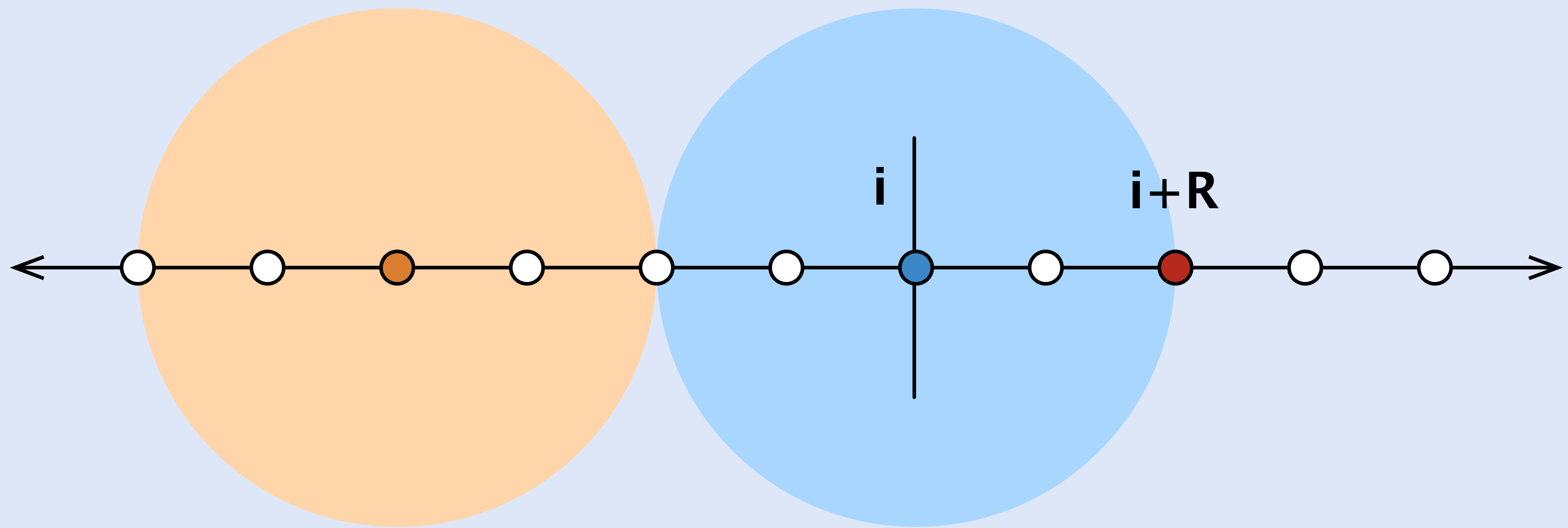
- Simultaneous transmission on multiple orthogonal channels
- Use of directional antenna for improved spatial throughput

Contributions of this paper

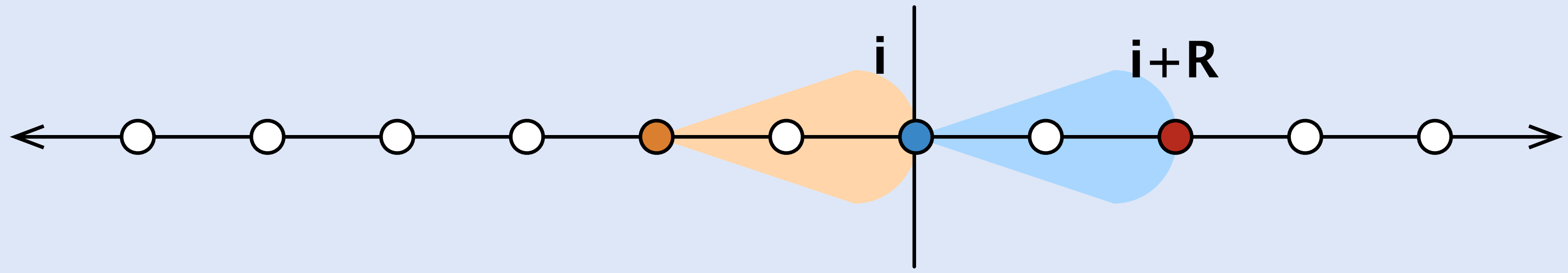
- Calls to be established over a single hop (needs channel assignment)
- Analyze channel assignment with rearrangement
- What is the probability that a given call is blocked/accepted?
  - Assuming we can rearrange all the existing calls

Omnidirectional and directional transmission

Omnidirectional transmission



Directional transmission



Transmission and interference ranges are assumed to be the same

Ignore side and back lobes for now

Network & traffic assumptions

Number of channels C; Range of transmission R

Call arrival process follows a Poisson process

Holding times are exponentially distributed with unit mean

All calls are one hop and bi-directional

- Node i generates calls only for nodes i + R
- Nodes i and i+R both act as transmitter and receiver

Number of calls originating at node i X_i

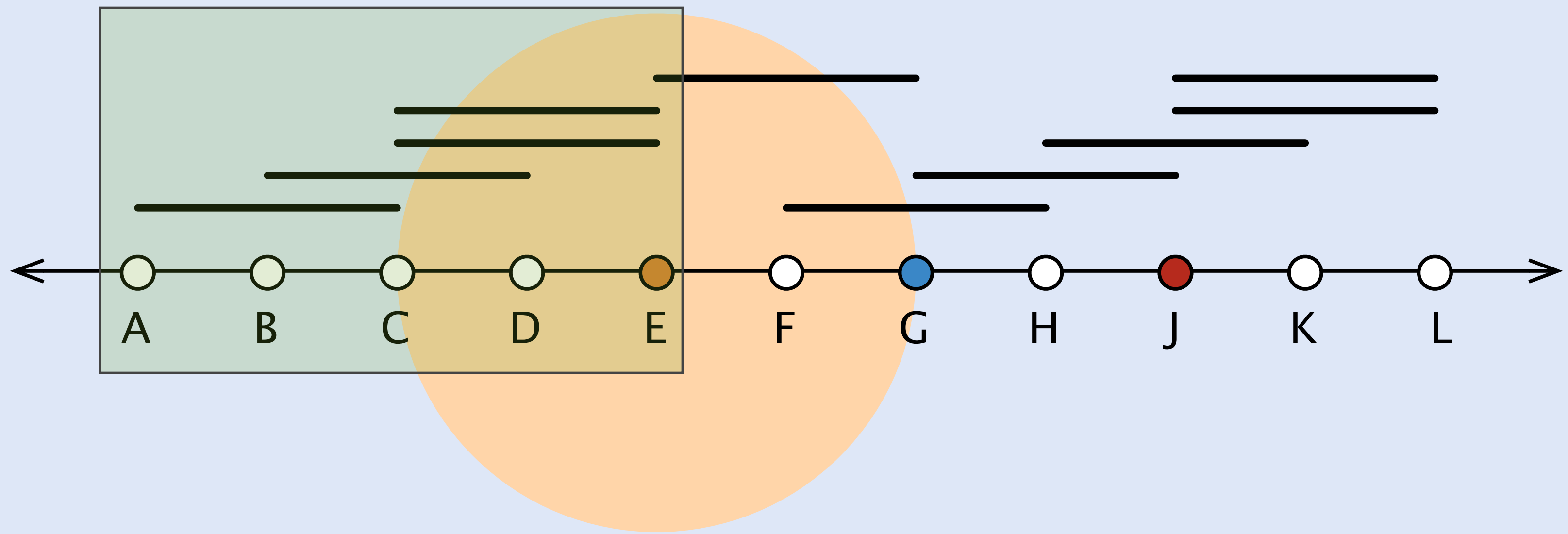
- Network may be viewed as an N-dimensional Markov Chain

Under what conditions a given call can be accommodated?

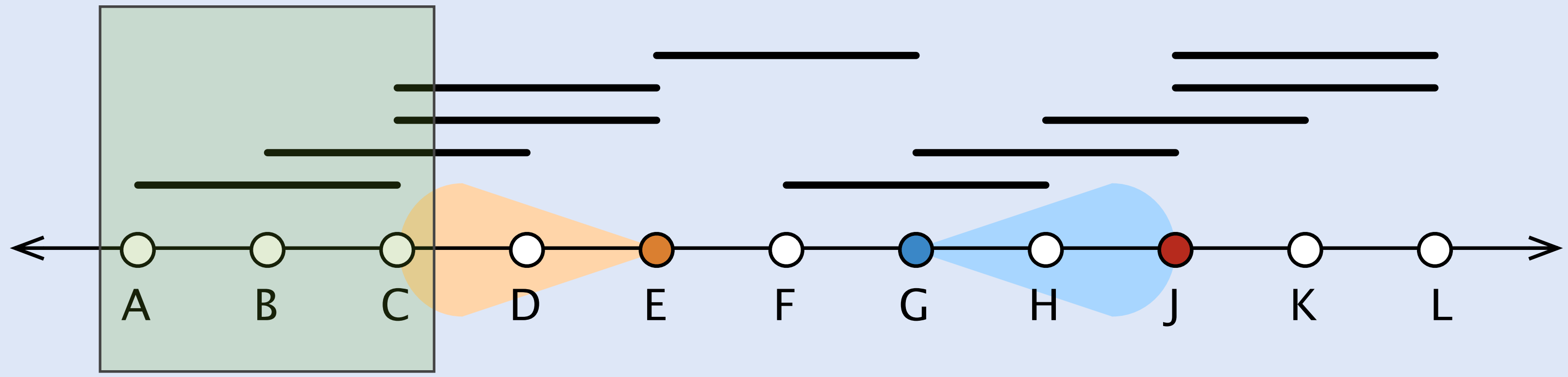
- Assuming that existing calls can be rearranged
- Treat the problem as a fresh channel assignment problem

Spatial reuse of channels

When omnidirectional antennas are employed



When directional antennas are employed



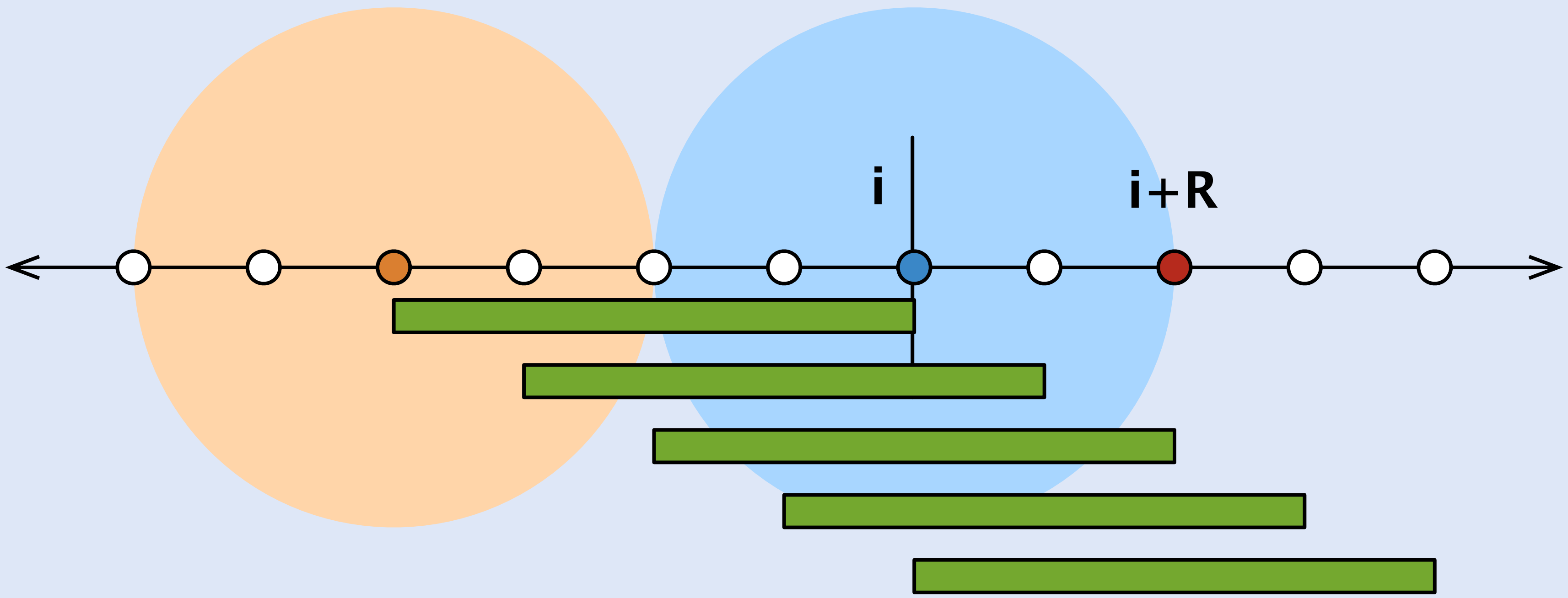
Omnidirectional case

Nodes i and i+R need to communicate

Number of calls originating in the window [k, k+2R]

$$V_k = \sum_{j=k}^{k+2R} X_j$$

Number of nodes in the window is 2R+1



Condition for call acceptance

$$V_k < C, \quad \forall k \in \{i - 2R, i\}$$

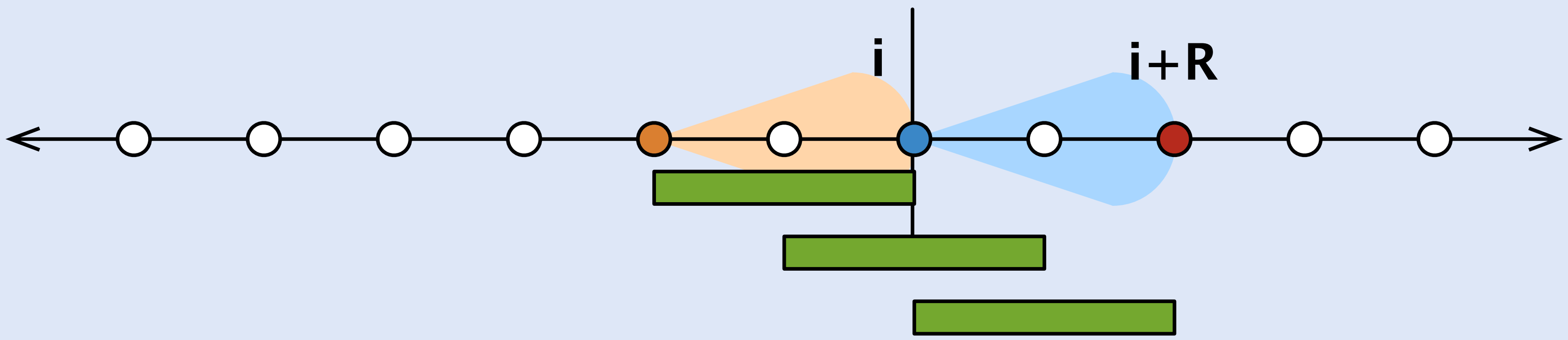
Directional case

Nodes i and i+R need to communicate

Number of calls originating in the window [k, k+R]

$$W_k = \sum_{j=k}^{k+R} X_j$$

Number of nodes in the window is R+1



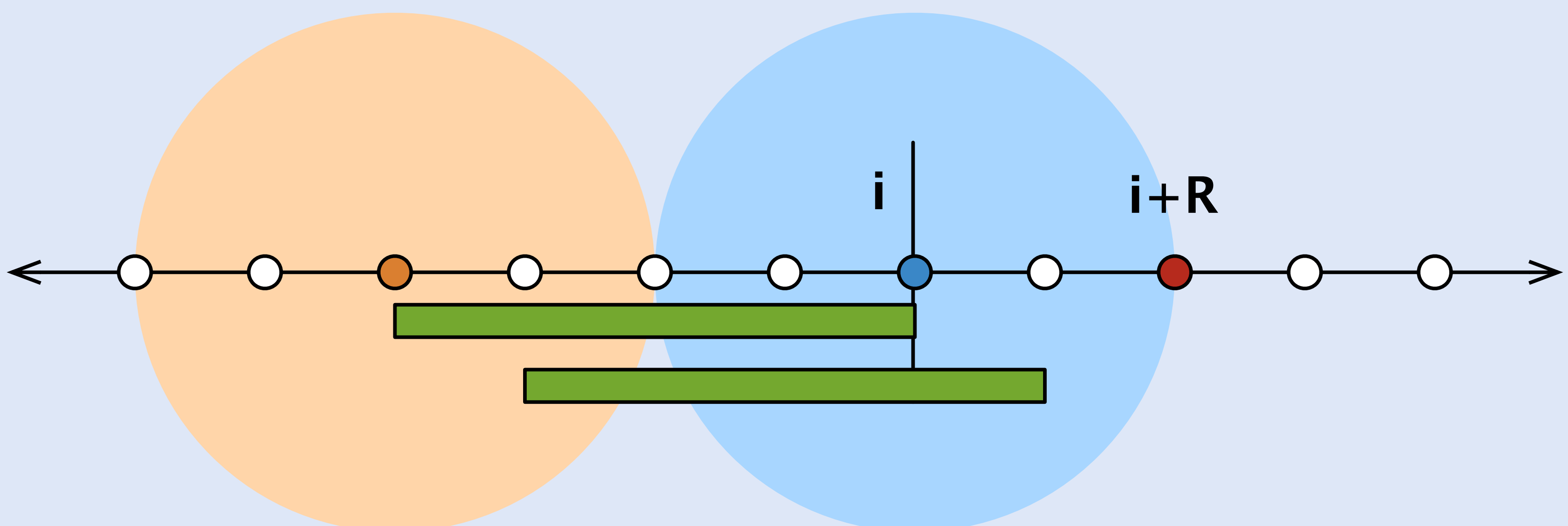
Condition for call acceptance

$$W_k < C, \quad \forall k \in \{i - R, i\}$$

Omnidirectional case - details

Joint distribution of calls in a window ($Y_k = V_k - X_k$)

$$P(X_k = x_k, Y_k = y_k) \quad = \quad \frac{1}{G_o} \frac{\rho^{x_k}(2R\rho)^{y_k}}{x_k! y_k!} \qquad G_o = \sum_{x_k=0}^{C} \sum_{y_k=0}^{C-x_k} \frac{\rho^{x_k}(2R\rho)^{y_k}}{x_k! y_k!}$$



$$P(V_{k+1} = v_{k+1} | V_k = v_k) =$$

$$\sum_{y_k=0}^{v_k} P(Y_k = y_k | V_k = v_k) P(X_{k+2R+1} = v_{k+1} - y_k | Y_k = y_k)$$

Omnidirectional case - details

Steady-state probability distribution of number of channels in a window

$$\pi = (\pi_0, \pi_1, \ldots, \pi_C)$$

Computation of steady-state probability

$$\pi \times P(V_{k+1} = v_{k+1} | V_k = v_k) = \pi$$

$$\sum_{c=0}^{C} \pi_c = 1$$

Omnidirectional case - details

$$
\begin{aligned}
P(V_{k+1} < C | V_k < C) &= \sum_{v_k=0}^{C-1} P(V_k = v_k | V_k < C) P(V_{k+1} < C | V_k = v_k) \\
&= \sum_{v_{k+1}=0}^{C-1} \sum_{v_k=0}^{C-1} P(V_k = v_k | V_k < C) \times \\
&\qquad P(V_{k+1} = v_{k+1} | V_k = v_k) \\
&= \sum_{v_{k+1}=0}^{C-1} \sum_{v_k=0}^{C-1} \frac{P(V_k = v_k)}{1 - P(V_k = C)} \times \\
&\qquad P(V_{k+1} = v_{k+1} | V_k = v_k)
\end{aligned}
$$

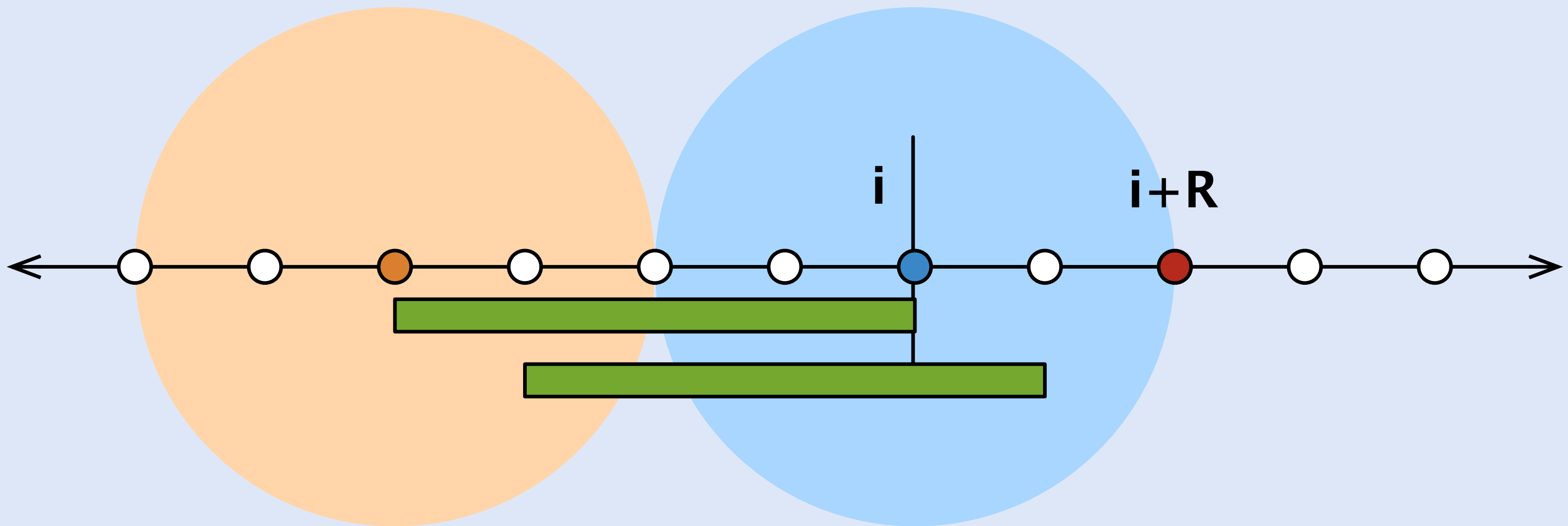
Success probability

$$
\begin{aligned}
P_{so} &= \pi(V_{i-2R} < C) \prod_{k=i-2R}^{i-1} P(V_{k+1} < C | V_k < C) \\
&= \pi(V_{i-2R} < C) P(V_{k+1} < C | V_k < C)^{2R}
\end{aligned}
$$

Directional case - details

Joint distribution of calls in a window ($Z_k = W_k - X_k$)

$$P(X_k = x_k, Z_k = z_k) \quad = \quad \frac{1}{G_d} \frac{\rho^{x_k}(R\rho)^{z_k}}{x_k! z_k!} \qquad G_d = \sum_{x_k=0}^{C} \sum_{z_k=0}^{C-x_k} \frac{\rho^{x_k}(R\rho)^{z_k}}{x_k! z_k!}$$



$$P(W_{k+1} = w_{k+1} | W_k = w_k)$$

$$\sum_{z_k=0}^{w_k} P(Z_k = z_k | W_k = w_k) P(X_{k+R+1} = w_{k+1} - z_k | Y_k = y_k)$$

Directional case - details

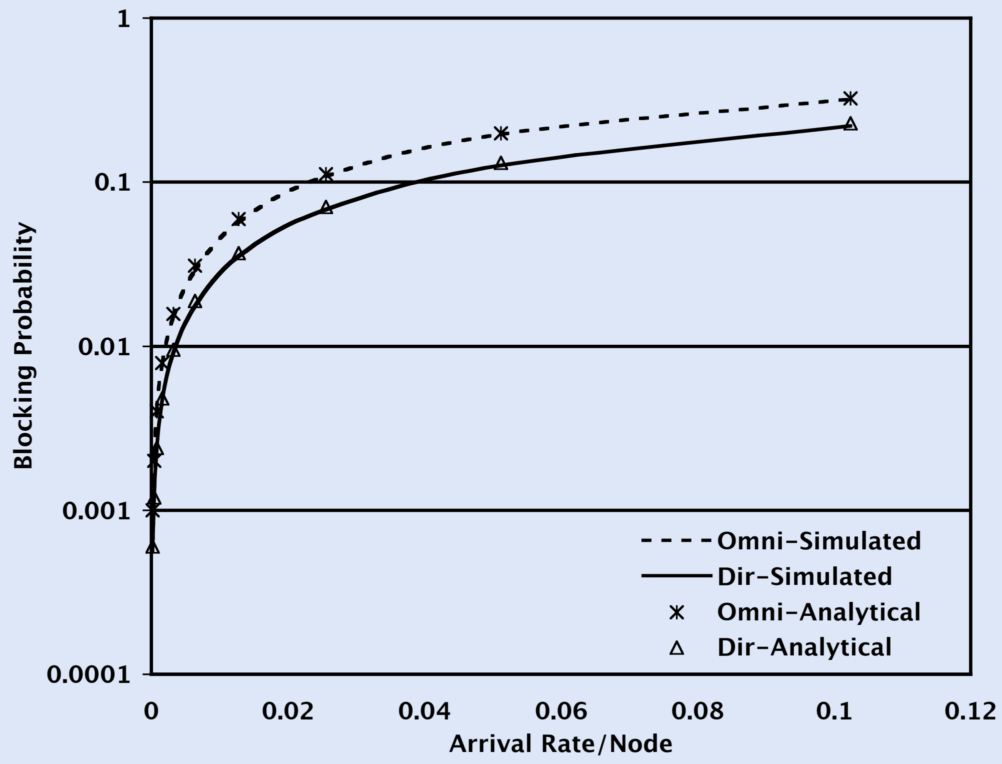
Compute steady-state probability as before

Note that only window size changes from 2R+1 to R+1

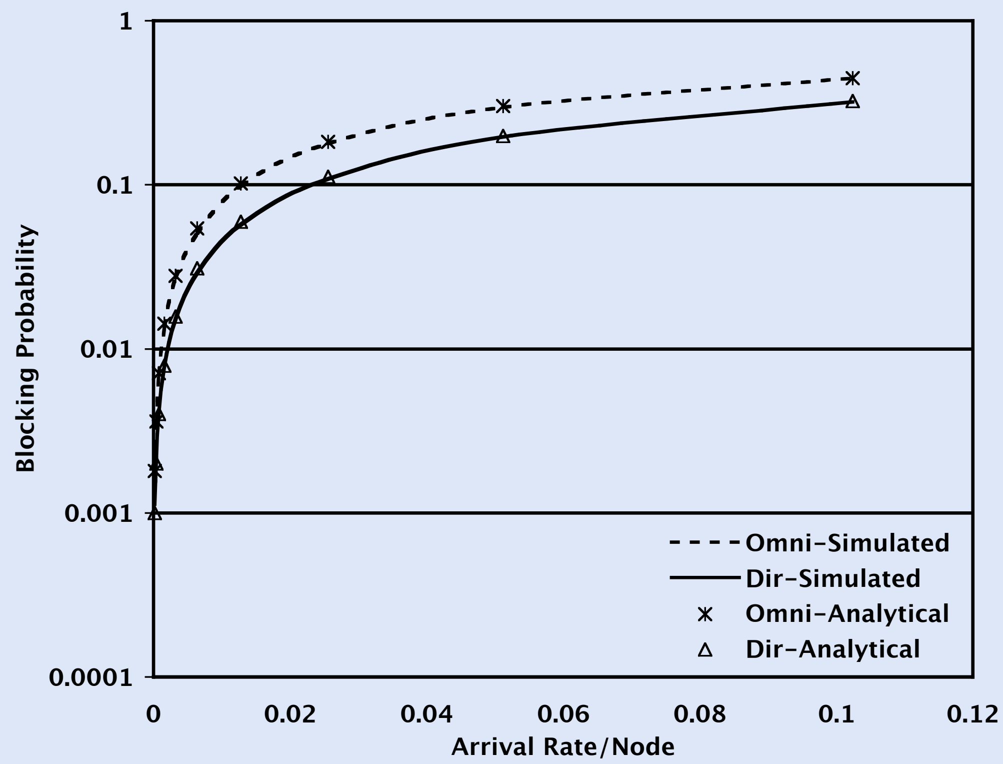
Call success probability

$$
\begin{aligned}
P_{sd} &= \pi(W_{i-R} < C) \prod_{k=i-R}^{i-1} P(W_{k+1} < C | W_k < C) \\
&= \pi(W_{i-R} < C) P(W_{k+1} < C | W_k < C)^R
\end{aligned}
$$

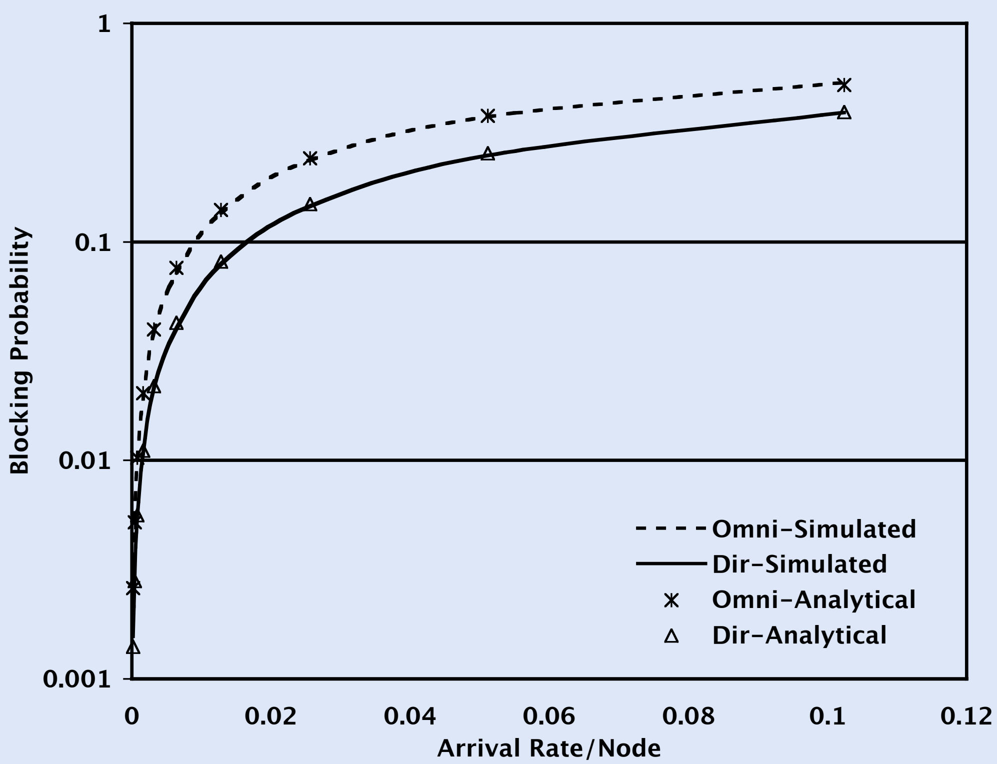
Performance results (1 channel)



R=1

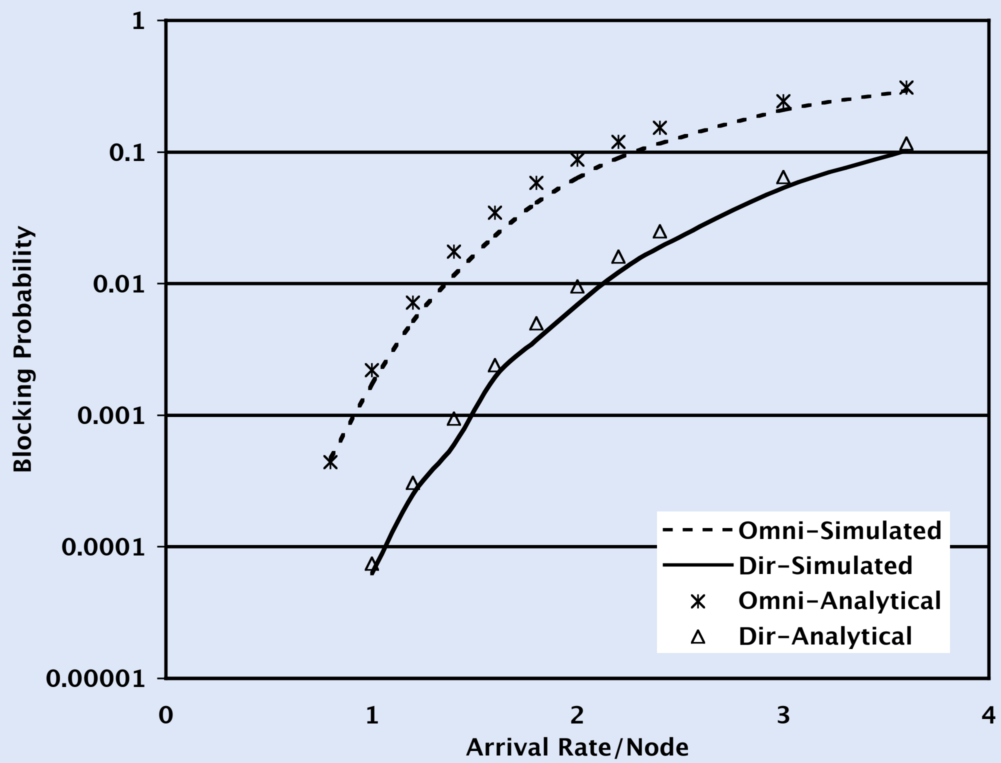


R=2

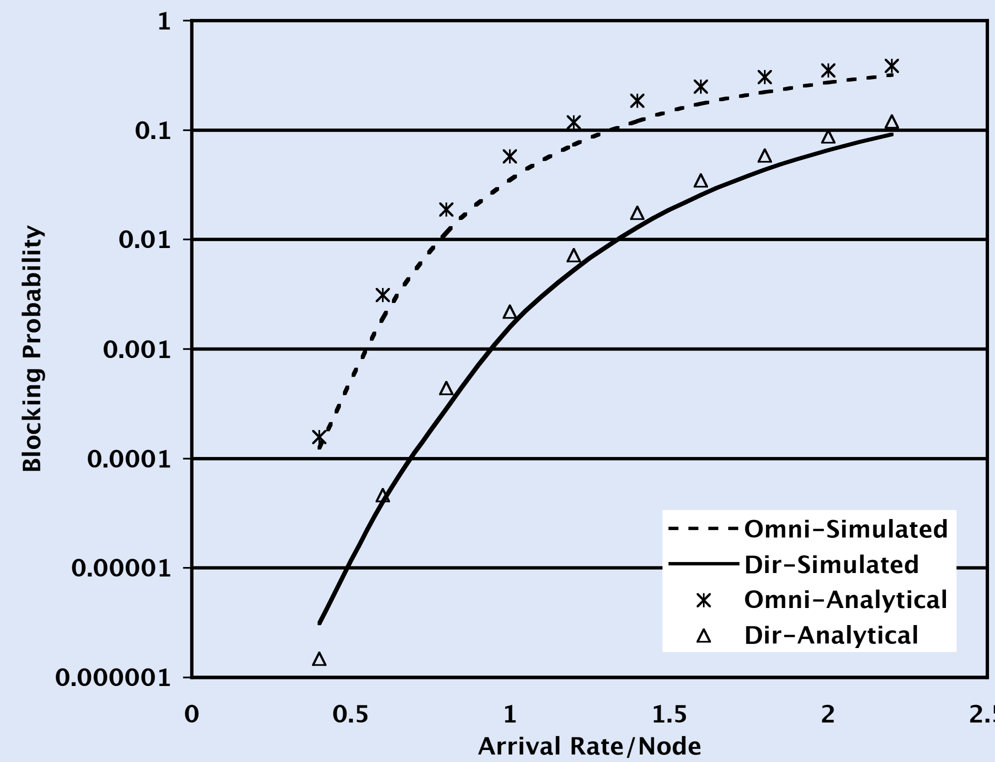


R=3

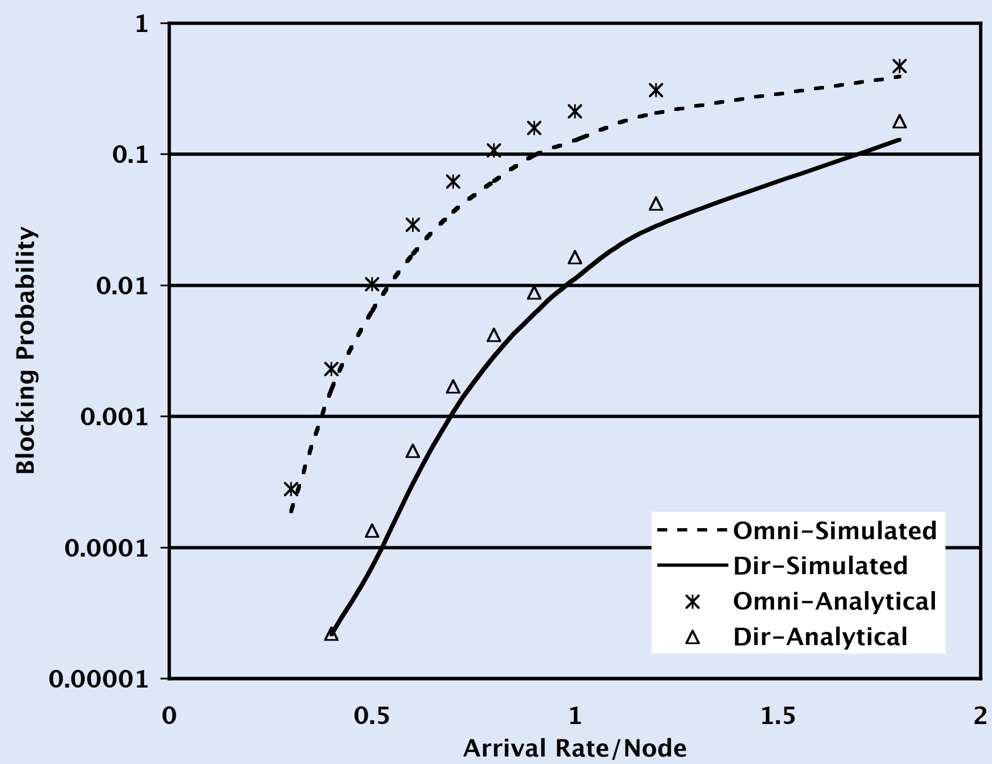
Performance results (10 channels)



R=1



R=2



R=3

Conclusion and future work

Analytical model for call blocking probability assuming

- Rearrangement of calls
- Interference and transmission ranges are identical
- Simulation results validate analytical model

Future work

- Assume that interference range is larger than transmission range
- Eliminate rearrangement
- Different transmission ranges over single-hop and multi-hop calls
- Relation to optical networks - Routing and wavelength continuity constraint

Application to channel access protocols

- Useful in quantifying the number of channels available at a node at any given time

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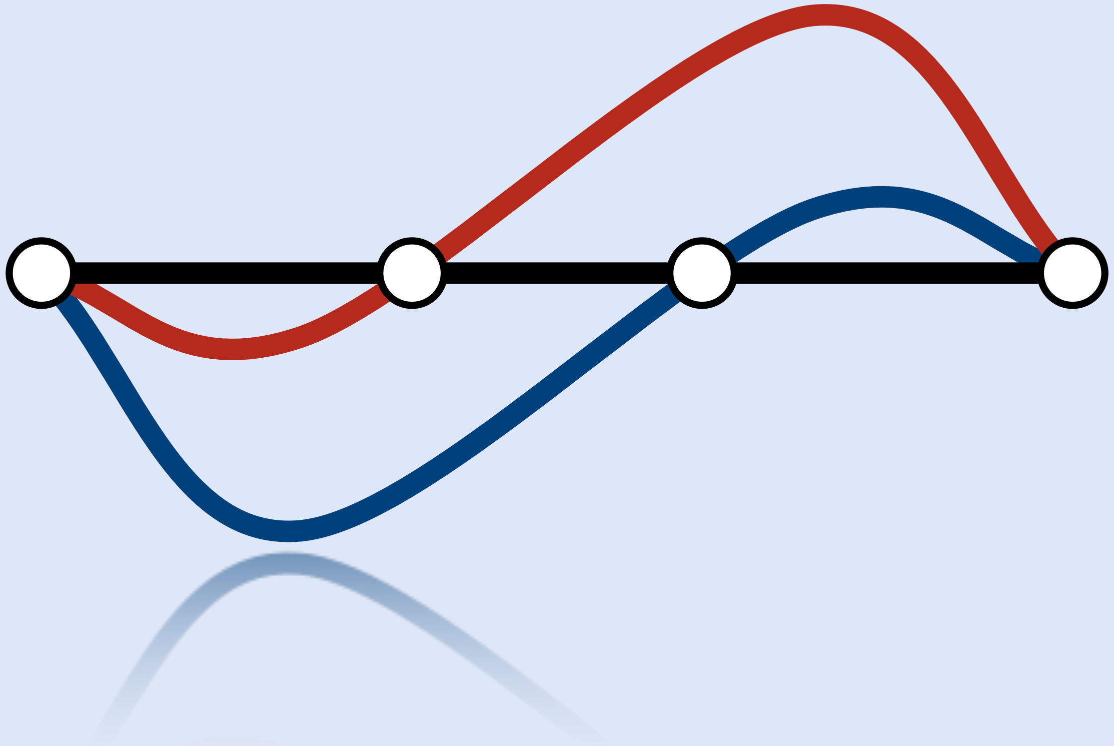

Acknowledgment

National Science Foundation [Grants: CNS-0325979; CNS-0435490]
Cisco Collaborative Research Initiative