Minimum Latency Broadcasting with Conflict Awareness in Wireless Sensor Networks

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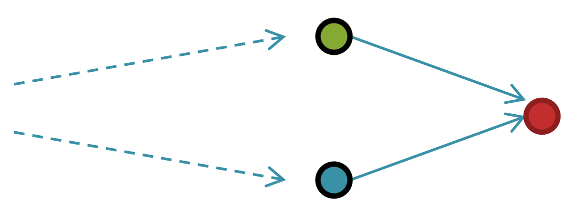
Outline

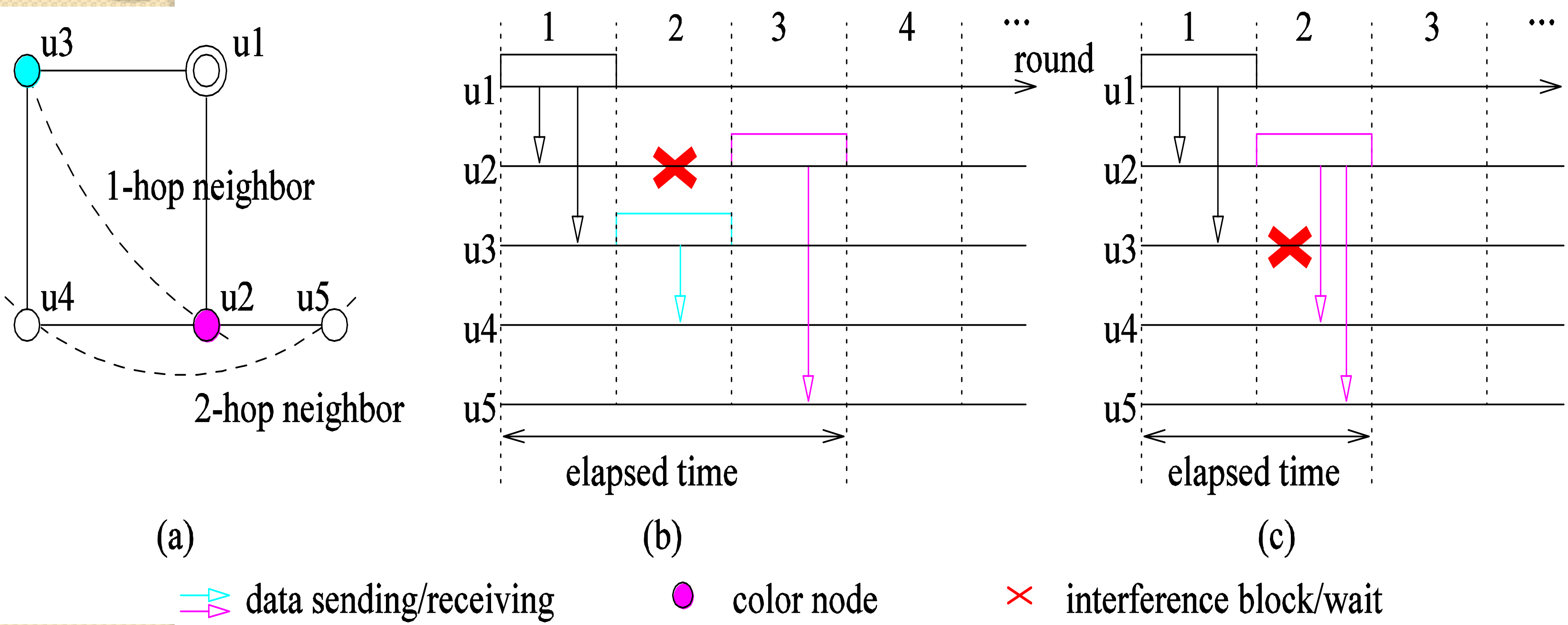
- Introduction
- Target Problem
- Our Approach
- Experimental Results
- Conclusion & Future Work

Introduction

- Apply pipeline to optimize the broadcasting performance in wireless sensor networks
  - Broadcasting is not a new problem
  - Existing methods adopt hop distance based flooding
- Broadcasting in wireless sensor networks
  - Conflict (by interference)
  - Color scheme
  - Color selection
  - Back-off delay

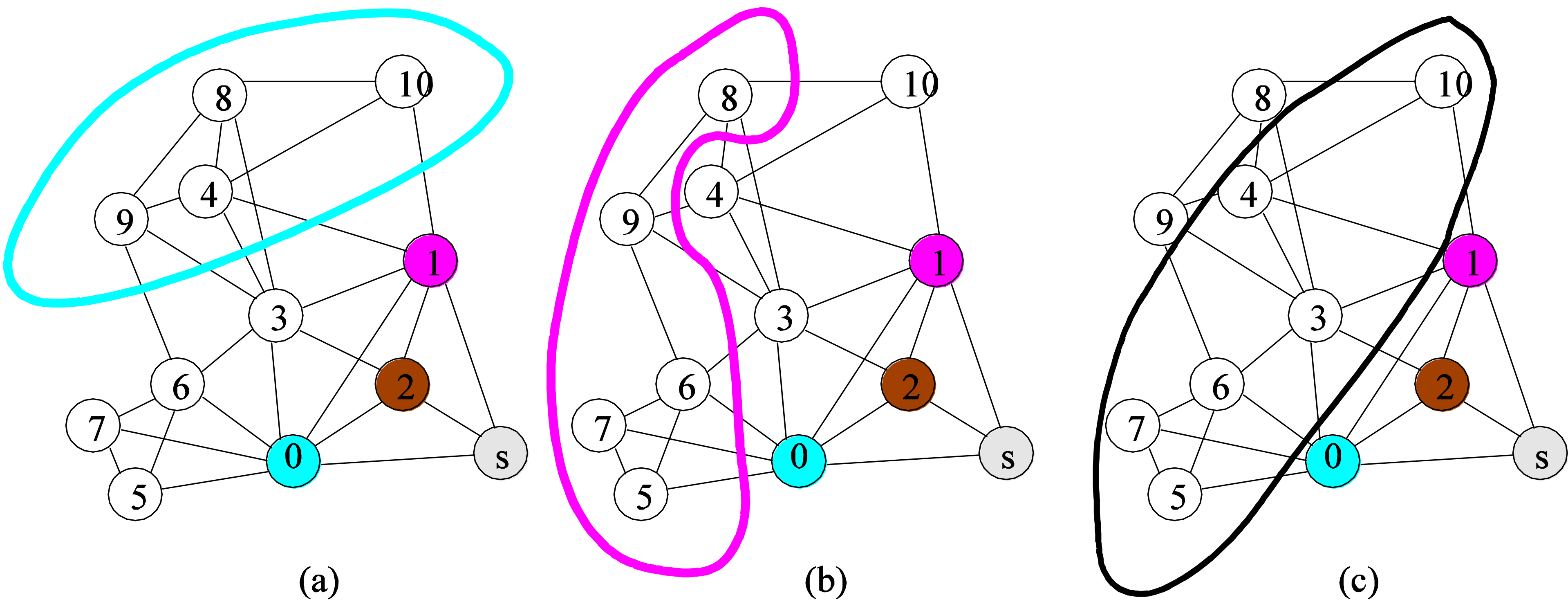


Sample of back-off delay and its impact



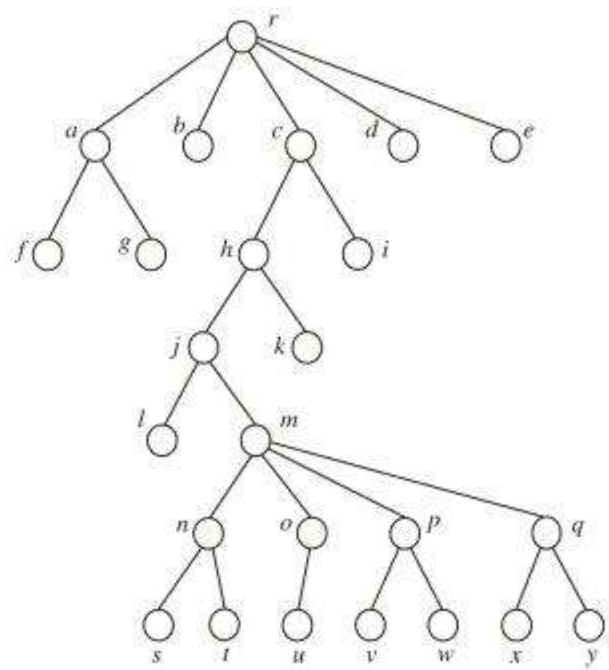
The problem is not trivial!

- Cannot be solved by using
  - Neighbor node degree
  - Pre-determined pair of sender and receiver
  - Network diameter or hop distance



Target Problem

- Can we pipeline the relays so that the back-off delay along the critical path can be reduced?



Goals

- The optimal solution for minimum latency broadcasting, by given the network deployment?
  - Greedy color scheme?
  - $(1+\varepsilon)$–estimation?
  - Hop distance?
- A more effective solution in the localized & distributed manner

Our approach

- Heuristic method is needed to find an optimal solution.
- To find a propagation in a color so that no other color selection can achieve better (faster) solution

$P(S) = \min\{t\}$

subject to :

$t = M(\{s\}, ts)$

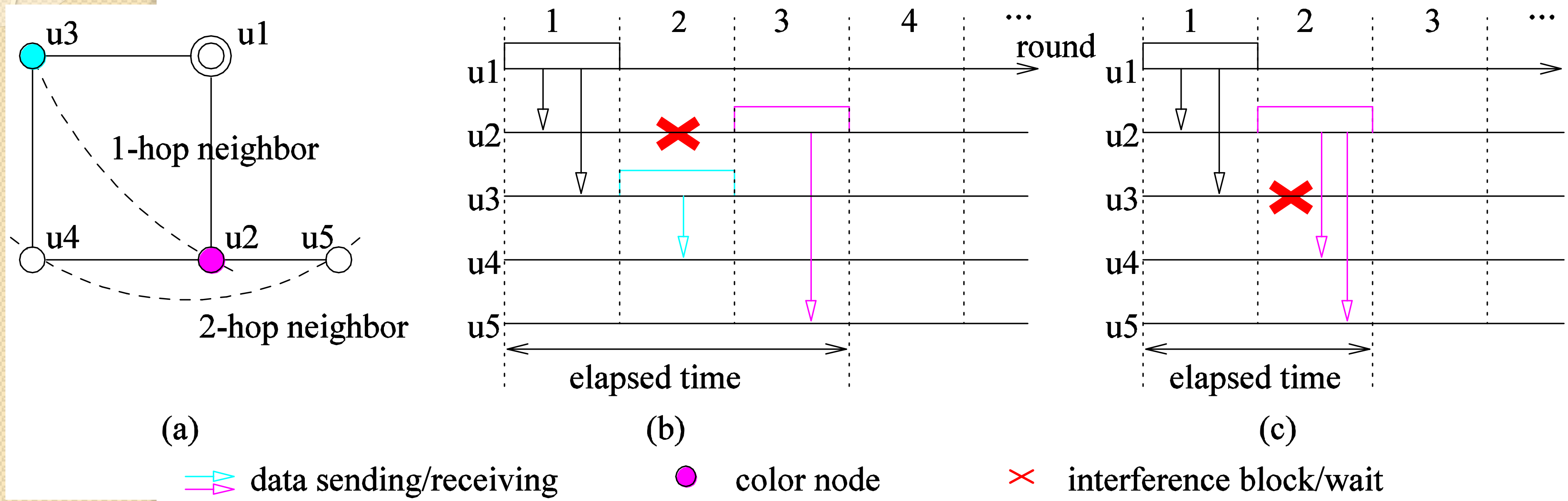
$M(N, t) = t - 1$, activity ends

$M(W, t) = M(W + A(W, t), t + 1)$ where A is the receivers of selected color relays $A(W, t) =$

$N(u) \mid \forall u \in Cs(w)\ \forall\ 1 \leq j \leq \lambda(W)$

$M(W + Cs(W), t+1) \leq M(W + Cj(W), t+1)$

- Color scheme: (e.g., Cs, Cj)
  - A valid progress in information propagation
  - Interference-freedom among all nodes in the same color
  - Conflict with a node in other colors (necessity of being labeled).

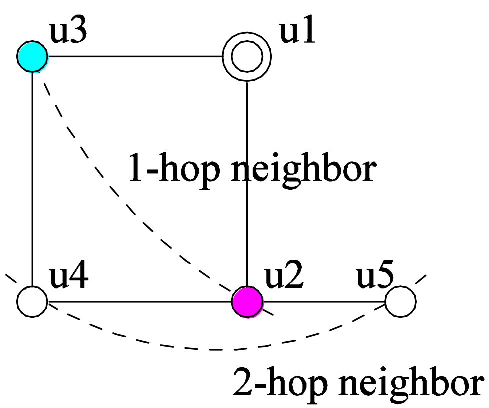


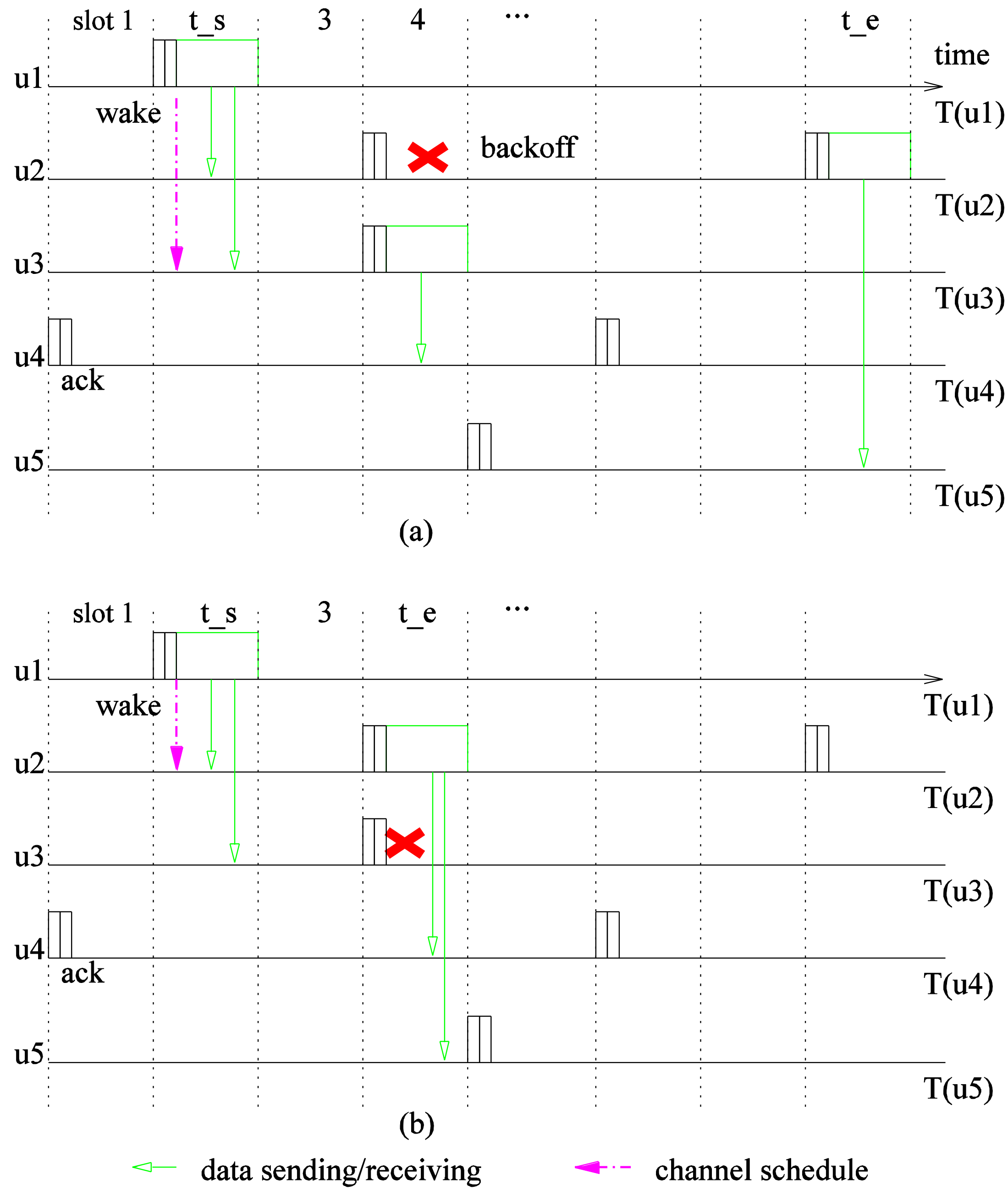
Task $\mathbb{B}(W,t)$, # of rounds	$\bigcup C_i$	$\bigcup \mathbb{B}$ in consideration	$C_{\mathbb{S}}$	$\mathbb{S}(W,t)$
$\mathbb{B}(\{1\},1)$	$C_1 : \{1\}$	$\mathbb{B}(\{1,2,3\},2)$	C_1	$\{2,3\}$
$\mathbb{B}(\{1,2,3\},2)$	$C_1 : \{2\}$ $C_2 : \{3\}$	$\mathbb{B}(N,3)$, $\mathbb{B}(\{1,2,3,4\},3)$	C_1	$\{4,5\}$
$\mathbb{B}(N,3)=2$				
$\mathbb{B}(\{1,2,3,4\},3)$	$C_1 : \{2\}$	$\mathbb{B}(N,4)$.		
$\mathbb{B}(N,4)=3$				

- Properties
  - Optimal performance
  - 2 + (hop distance)

- Extension under the greedy coloring scheme:
  - A new constraint:
    - The more receivers it connected, the earlier this sender will be labeled in the color scheme.

- Duty cycle system
  - Round -> slot

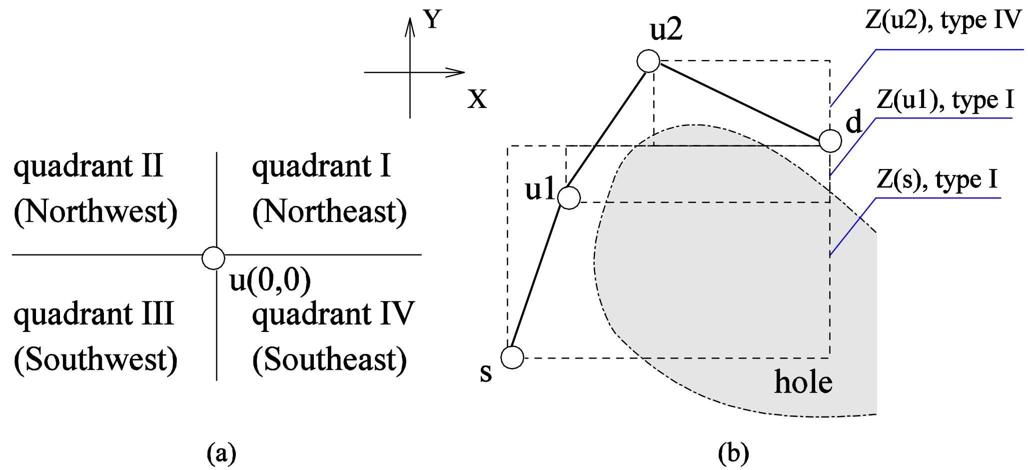

u3
u1
1-hop neighbor
u4
u2
u5
2-hop neighbor


slot 1
t_s
3
4
…
t_e
time
u1
u2
u3
u4
u5
wake
backoff
ack
T(u1)
T(u2)
T(u3)
T(u4)
T(u5)
(a)
slot 1
t_s
3
t_e
…
u1
u2
u3
u4
u5
wake
ack
T(u1)
T(u2)
T(u3)
T(u4)
T(u5)
(b)
data sending/receiving
channel schedule

Task $\mathbb{B}(W,t)$, # of rounds	$\bigcup C_i$	$\bigcup \mathbb{B}$ in consideration	$C_{\mathbb{S}}$	$\mathbb{S}(W,t)$
$\mathbb{B}(\{1\},2)$	$C_1 : \{1\}$	$\mathbb{B}(\{1,2,3\},3)$	C_1	$\{2,3\}$
$\mathbb{B}(\{1,2,3\},3)$	N/A	$\mathbb{B}(\{1,2,3\},4)$	N/A	ϕ
$\mathbb{B}(\{1,2,3\},4)$	$C_1 : \{2\}$ $C_2 : \{3\}$	$\mathbb{B}(N,5) = 4$, $\mathbb{B}(\{1,2,3,4\},5)$	C_1	$\{4,5\}$
$\mathbb{B}(\{1,2,3,4\},5)$	N/A	$\mathbb{B}(\{1,2,3,4\},6)$	N/A	ϕ
$\ldots$		$\ldots$		
$\mathbb{B}(\{1,2,3,4\},\xi+3)$	$C_1 : \{2\}$	$\mathbb{B}(N,\xi+4) >> 4$		

- Costly?
- A cost-effective method is needed (in both round-based and duty cycle systems).

- Each node has four regions



- For each region, a node has a metric value H (i.e., distance to the edge of network in this region): H(u) = 1 + min { H(v)}

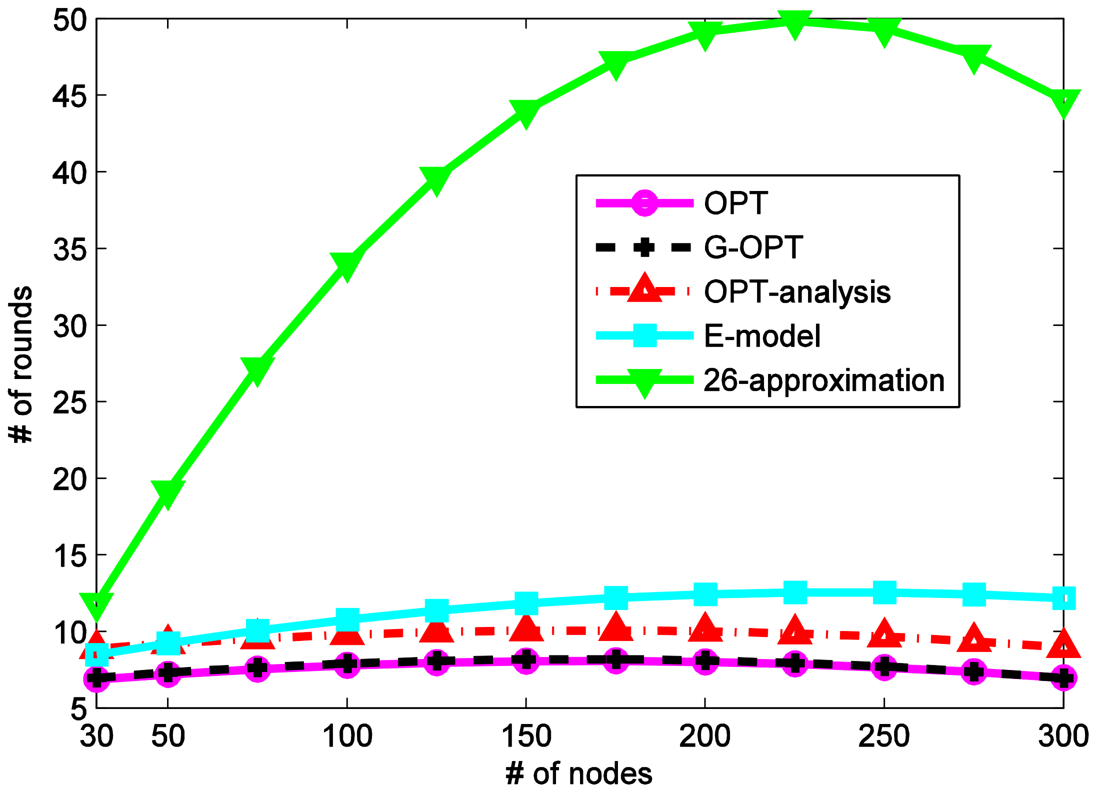
- To find Cs

$$B(W + Cs(W), t+1) \leq B(W + Cj(W), t+1)$$

Cs = Cj where $u \in Cj$ has the largest H in neighborhood

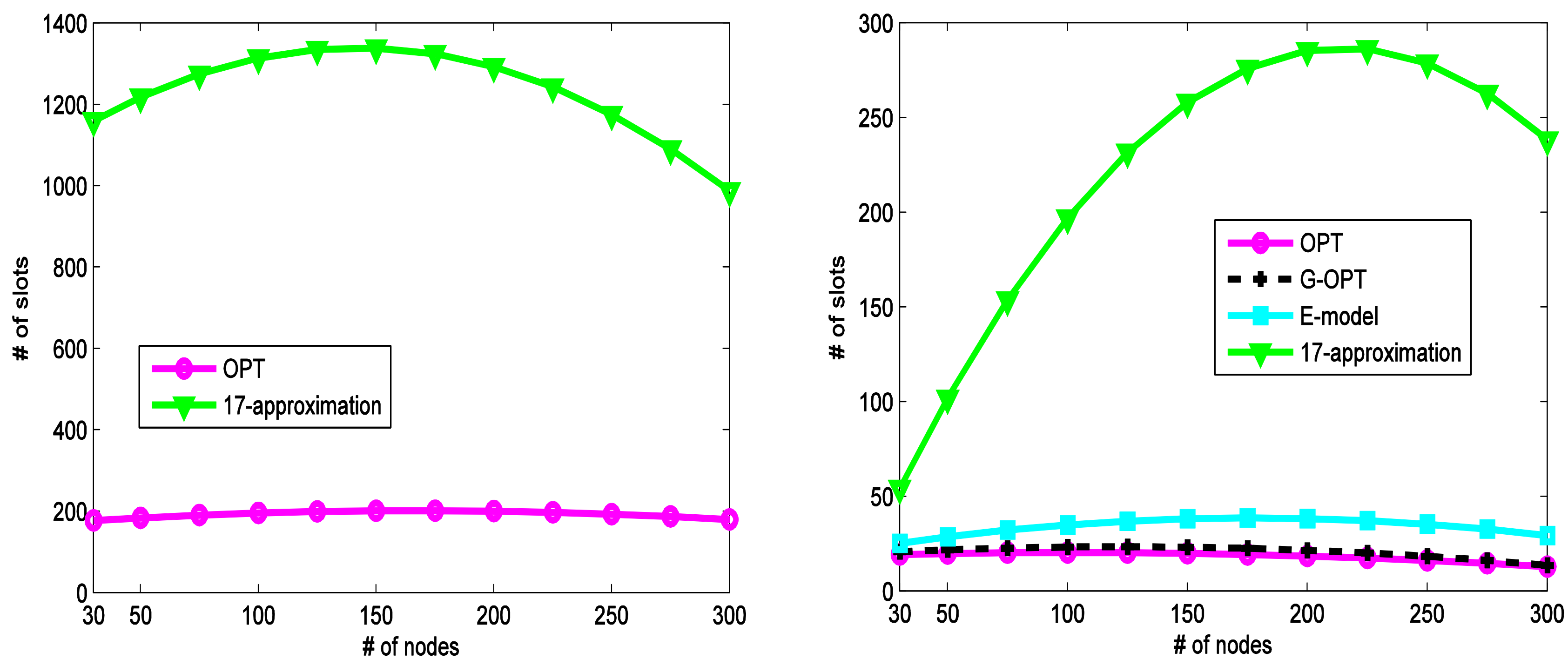
Experimental Results

- Round based system



Experimental Results

- Duty cycle system (10%)



Conclusion

- Some new insights brought by pipeline
  - Effectiveness of greedy coloring scheme
  - Consideration of hop distance
  - Problem in pre-determined end set in process
- Optimal solution
- A better estimation solution with the consideration of the computational complexity and cost

Future Work

- Localized color scheme
- A more effective localized & distributed solution
- The broadcasting optimization with other constraints such as energy and traffic throughput
- Extension in other cyclic network deployments (e.g., vehicle networks)

Thank you!

- Questions and Comments