# Approximation Algorithm for Data Broadcast in Wireless Networks

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# Contribution

- A 12-approximation algorithm for ONE-TO-ALL BROADCAST problem, which is better than approximation guarantee of 16 due to Huang *et. al.*
- Two approximation algorithms for ALL-TO-ALL BROADCAST problem with approximation guarantees of 20 and 34 respectively. Thereby improving the approximation guarantee of 27 by Huang *et. al.*

# Preliminaries

- **Network Model:** The network is modeled as a Unit Disk Graph (UDG).
- **Problem Statement:** Minimum Latency Broadcast Scheduling.

# ONE-TO-ALL BROADCAST ALGORITHM

- Generate a broadcast tree, such that the tree forms a connected dominating set of the network.
  - Primary Nodes (Dominator nodes)
  - Secondary Nodes (Connector nodes)
- Phase 1: The broadcast is performed within the broadcast tree to inform all the dominating nodes in the tree.
- Phase 2: All the dominating nodes in the tree broadcast the message to all their uninformed neighbors.

# ONE-TO-ALL BROADCAST ALGORITHM

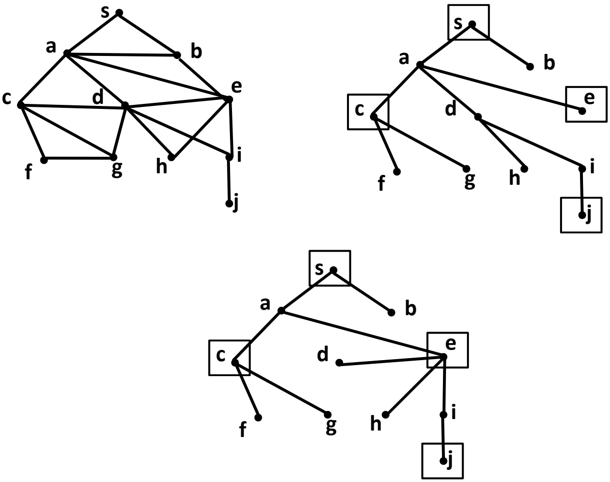



Illustration of the Algorithm

# ONE-TO-ALL BROADCAST ALGORITHM

The two key differences from the algorithm in [4] that lead to a significantly improved approximation guarantee are:

- Processing the nodes in a greedy manner while constructing the broadcast tree.
- Allowing a node to transmit more than once.

# ONE-TO-ALL BROADCAST ALGORITHM

BROADCASTTREE$(G = (V, E), s)$

$P \leftarrow P_0 \leftarrow \{s\}$ // $P$ is the set of primary nodes.<br>
$T_{BFS} \leftarrow$ BFS tree in $G$ with root $s$<br>
$\ell \leftarrow$ maximum number of levels in $T_{BFS}$ // $s$ belongs to level 0<br>
**for** $i \leftarrow 1$ to $\ell$ **do**<br>
 $L_i \leftarrow$ set of all nodes at level $i$ in $T_{BFS}$; $P_i \leftarrow \emptyset$<br>
 **for each** $w \in L_i$ **do**<br>
  **if** $(P \cap D(w) = \emptyset)$ **then**<br>
   $P_i \leftarrow P_i \cup \{w\}$; $P \leftarrow P \cup \{w\}$<br>
 $S_i \leftarrow L_i \setminus P_i$<br>
$P_{\ell+1} \leftarrow \emptyset$; $S \leftarrow V \setminus P$<br>
**for each** node $u \in V$ **do**<br>
 $parent(u) \leftarrow$ NIL<br>
**for** $i \leftarrow 0$ to $\ell$ **do**<br>
 $P'_i \leftarrow P_i$<br>
 **while** $(P'_i \neq \emptyset)$ **do**<br>
  $u \leftarrow$node in $P'_i$ with maximum<br>
   $|\{w | w \in D(u)$ and $parent(w) = \text{NIL}\}|$<br>
  $C(u) \leftarrow \{w | w \in D(u)$ and $parent(w) = \text{NIL}\}$<br>
  **for each** $w \in C(u)$ **do**<br>
   $parent(w) \leftarrow u$<br>
  $P'_i \leftarrow P'_i \setminus \{u\}$<br>
 **while** $(\exists w \in P_{i+1}$ s.t. $parent(w) = \text{NIL})$ **do**<br>
  $u \leftarrow$node in $S_i$ with maximum<br>
   $|\{w | w \in D(u) \cap P_{i+1}$ and $parent(w) = \text{NIL}\}|$<br>
  $C(u) \leftarrow \{w | w \in D(u) \cap P_{i+1}$ and $parent(w) = \text{NIL}\}$<br>
  **for each** $w \in C(u)$ **do**<br>
   $parent(w) \leftarrow u$<br>
$V_b \leftarrow V$; $E_b \leftarrow \{(u, w) | u = parent(w)\}$<br>
**return** $T_b = (V_b, E_b)$

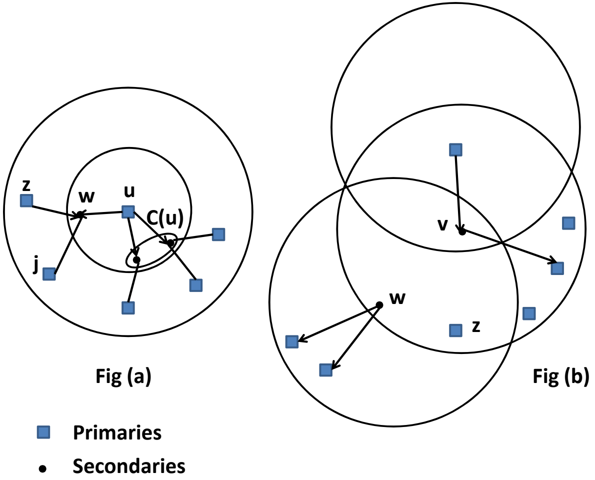
# ONE-TO-ALL BROADCAST ALGORITHM

**Lemma**

*Let $u \in P_i$. Suppose that in Phase 1, a transmission from $u$ is delayed due to the transmission from a primary node $z$ in $D_p(u, 2) \bigcap P_i$, as $z$ interferes with $u$ at $w$. Then the following is true.*

- *$w$ is not in $C(u)$.*
- *For each $z$, there is at least one unique primary node in $D_p(u, 2)$ that does not interfere with $u$.*

# ONE-TO-ALL BROADCAST ALGORITHM




Fig(a): Proof of lemma 1, Fig(b): Proof of lemma 3

# ONE-TO-ALL BROADCAST ALGORITHM

## Lemma

*Consider a node* $u \in P_i$, $0 < l$. *Let* $v$ *be a secondary node in* $C(u) \bigcap X$.
*Then* $trTime_1(u) \leq$
$t_{i-1} + \left\lfloor (17 - \left| \bigcup_{v \in C(u) \bigcap X} (P_{i+1}(v)_{i+2}(v)) \right|)/2 \right\rfloor \leq t_{i-1} + 9.$

## Lemma

*Let* $v$ *be a secondary transmitter in* $L_i$, $0 \leq i \leq l$.
*Then* $trTime_1(v) \leq t_{i-1} + 12.$

# ONE-TO-ALL BROADCAST ALGORITHM

**Lemma**

*For $0 \leq i \leq l-1$, the time by which all the transmitters in $L_i$ transmit the message once is $t_i \leq t_{i-1} + 12$.*

**Theorem**

*The approximation algorithm gives a 12-approximate solution for the latency. The number of transmission are 21 times those in an optimal solution.*

# All-to-ALL BROADCAST ALGORITHM

**Lemma**

*The minimum latency of all-to-all broadcasting in G is at least* $n - 1 + \gamma_c$.

# Collect-and-Distribute Algorithm (CDA)

- **PHASE 1:** Node $s$ collects all the messages by using the data collection algorithm. The latency of the collection algorithm is $3(n-1)$
- **PHASE 2:** The node $s$ performs $One - to - All$ broadcast of the individual messages collected in phase 1.
  - Generate $H_1$ and $H_2$ of the primary nodes and the secondary nodes.
  - Schedule the primaries in $H_1$ and secondaries in $H_2$ based on the vertex coloring performed in the first-fit manner in the smallest degree last ordering.
  - Number of colors used to color $H_1$ are $k_1 \leq 12$, whereas number of colors used to color $H_2$ are $k_2 \leq 5$.

**Lemma**

*The second phase takes no more than* $17(n - 1 + R)$ *time steps.*

**Theorem**

*The all-to-all broadcasting algorithm CDA gives* 20*-approximation.*