DPDP: An Algorithm for Reliable and Smaller Congestion in the Mobile Ad-Hoc Network

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Abstract. The PDP(Partial Dominant Pruning) method is known as most practical method to reduce overlapped broadcasting messages by designating forward node as in-fly type when broadcasting occurs in the mobile wireless network with directional antenna. In this paper, we introduce DPDP(Directional PDP) that reduces not only number of nodes but number of used antenna elements simultaneously. By simulation, we proved our algorithm reduces number of forwarding nodes per antenna element and number of overlapped messages that each node receives compare to PDP though the number of antenna elements are increasing rather than in case of using omnidirectional antennas.

Keywords: partial dominant pruning, selected broadcasting, mobile ad-hoc network.

1 Introduction

Because all nodes roll not only host, but router, it is necessary to use broadcasting in the mobile ad-hoc network to find routing path to a certain node or discover locational information. In general, to deal with Broadcast storm, the method that message forwarding is performed by only fixed nodes in the mobile ad-hoc network are used[1][2][3][4]. These forwarding nodes come under CDS(Connected Dominent Set) to the network, but finding the lowest cost CDS is known as NP-complete problem. The heuristic to designate CDS is consists of source-independent broadcasting and source-dependent broadcasting[1][3][5][6]. A source-independent broadcasting consists only one CDS per given network and source-dependent broadcasting consists CDS based on broadcasting node by in-fly form. So source-dependent broadcasting method can have a few CDSs but source-independent broadcasting does not. In general, source-independent broadcasting garantees smaller number of nodes but source-dependent broadcasting is fit for dynamic situation.

The mobile ad-hoc network with directional antenna is known as good for bandwidth use and power consumption and can reduce interference with neighbor node, but due to technical difficulty, the research which broadcasting method with directional

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antenna in the mobile ad-hoc network has started lately. Most researches is research that designates CDS using source-independent broadcasting method and research that try to reduce redundancy broadcasting messages by considering antenna's direction[6][7]. But there are no research that designates message forwarding nodes set based on broadcasting node like this paper. In this paper, we proposed directional partial dominant pruning that expanded version of PDP which reduces not only number of antenna elements but also number of forwarding nodes[1]. By simulation, we proved that our algorithm is superior than legacy PDP from the viewpoint of reducing number of nodes and antenna elements.

2 Network Model

Fig. 1 shows omnidirectional antenna and directional antenna, Fig. 2 shows switched beam antenna that divided to fanwise sector for 360° and each sector has antenna element of it's own[8][9].

In case that omni-directional antenna using 10dBm power reaches 250m, but using the same antenna which beam angle setted by 60° , it reaches 450m[9]. A switched beam antenna that using only one antenna element at a time, omnidirectional broadcasting can be realized by sequential sweeping process[8]. We supposed u's neighbor nodes to u can reach and declare u's neighbor nodes set to $N(u)$. By definition, $u \in N(u)$. If we declare u's 2-hop neighbor nodes set to $N(N(u))$ or $N_2(u)$, a inequality $\{u\} \subseteq N(u) \subseteq N_2(u)$ is established and $N(v) \subseteq N_2(u)$ follows if $v \in N(u)$. If we declare $N_h(u)$ that within h-hop nodes from u and $H_h(u)$ that h-hop nodes from u, a following equation comes, $H_h(u) = N_{h-1}(u) \cup H_h(u)$ where $h \geq 1$ and $N_0(u) = H_0(u) = \{u\}$. For the convenience, we omit subscript if $h = 1$.

Nodes can communicate directly with antenna element i, where the nodes which using unoverlaped K antenna elements, so to speak 1-hop away nodes set declared to $N_{i\rightarrow}(u)$. Then $N_{i\rightarrow}(u) \subseteq N(u)$ and $N(u) = N_{o\rightarrow}(u) \cup N_{2\rightarrow}(u) \cup ... \cup N_{K-1\rightarrow}(u) \cup \{u\}$.

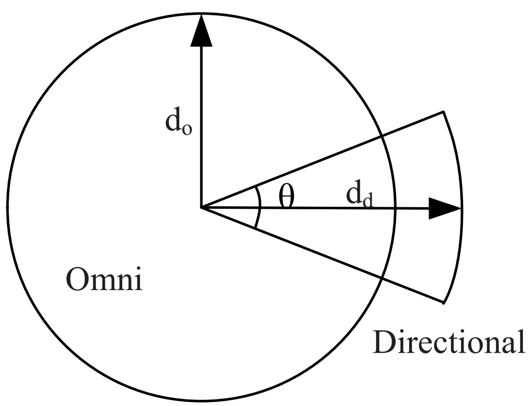

Fig. 1. Omnidirectional antenna and directional antenna

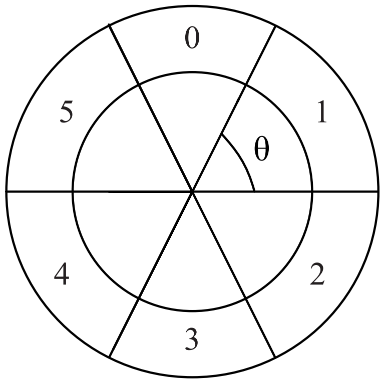

Fig. 2. Directional antenna which consist of 6 antenna elements(K=6)

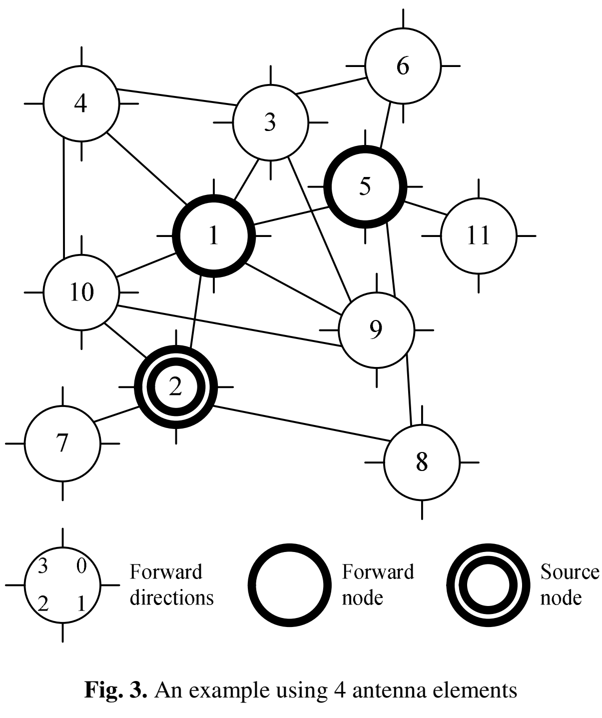

Fig. 3. An example using 4 antenna elements

Because radiowave travels straight, there are diagonal relationship established between antenna elements for u and v (where $u \in N(v)$) communicate each other. In other words, the antenna j where $0 \le j \le K-1$ which transmit messages u to v, the antenna that v uses must $(j+(K/2)) \bmod K$.

In Fig. 3, the antenna is 1 when node 2 transmit messages to node 8, so node 8 can receive message from node 2 via antenna 3.

If $D_{v \to u} = \{i \mid u \in N_{i \to}(v)\}$, $D_{v \to V} = D_{w \in V} \bigcup D_{v \to w}$ where V is nodes set that satisfy $V \subseteq N(v)$. For example, $D_{8 \to 2} = \{3\}$, $N(10) = \{1,2,4,9\}$, $D_{10 \to N(10)}$ $= D_{10 \to 1} \bigcup D_{10 \to 2} \bigcup D_{10 \to 4} \bigcup D_{10 \to 9} = \{0\} \bigcup \{1\} \bigcup \{0\} \bigcup \{1\} = \{0,1\}$ in Fig. 3.

In this paper, we suppose that node u broadcast HELLO periodically for obtain neighbor node's state information. In other words, node v that receives HELLO from u, transmits HELLO to u via piggybacking to communicate with 1-hop neighbor node $N(v)$.

3 Directional Partial Dominant Pruning

To apply PDP that designed for omnidirectional antenna model to directional antenna model, we considered followings.

- We modified selection criterion for node that belongs to $B(u,v)(= N(v) - N(u))$ and covers node under $U(u,v)(= H_2(v) - N(u) - N(N(u) \bigcap N(v)))$, that is, we selected node p that covers q where $q \in U(u,v)$ and $Max(| N(p) \bigcap U(u,v) |)$ where $p \in B(u,v)$ preferentially. If tie occurs, we selected p where $Max(| N(p) \bigcap U(u,v) |)$, and if tie orrurs again, we select random node.
- Then we found out antenna elements set $D_{v \to B(u,v)}$ which used for message forwarding to node belongs to $B(u,v)$, that is, 1-hop node from v which have to receive message including selected $F(v)$. Not a like omnidirectional antenna model, directional antenna model must transmit to only receiving node's direction to reduce interference and waste of bandwidth.

Algorithm: DPDP(Directional Partial Dominant Pruning)

input: $N(v)$, $N_2(v)$, $F(u)$

output: $F(v)$, $D_{v \to B(u,v)}$

initial state: $F(v) = D_{v \to B(u,v)} = \phi$

1. $B(u,v) = N(v) - N(u)$,
$U(u,v) = H_2(v) - N(u) - N(N(u) \bigcap N(v))$

2. if t where $t \in U(u,v)$ is covered by s where $s \in B(u,v)$, do following

 2.1 $F(v) = F(v) \bigcup \{s\}$, $D_{v \to B(u,v)} = D_{v \to B(u,v)} \bigcap D_{v \to s}$

 2.2 $B(u,v) = B(u,v) - s$, $U(u,v) = U(u,v) - \{N(s) \bigcap U(u,v)\}$

3. perform repeatedly until $U(u,v) = \phi$

 3.1 find $D_{v \to B(u,v)} = D_{v \to B(u,v)} \bigcup \{i\}$ for p where $Max(| N(p) \bigcap U(u,v) |)$, if tie occurs then jump to,

otherwise jump to 3.3
3.2 find p where $Max(|N(p) \bigcap U(u,v)|)$, if tie occurs again then find p where $Max(|H(p)|)$, and if tie occurs again then select random p, then find $D_{v \to B(u,v)} = D_{v \to B(u,v)} \bigcup D_{v \to p}$
3.3 $F(v) = F(v) \bigcup \{p\}$
$B(u,v) = B(u,v) - p \quad U(u,v) = U(u,v) - \{N(p) \bigcap U(u,v)\}$

Fig. 3 shows that $F(v)$ in case of node 2 is broadcasting source. In node 2, $B(\phi,2) = N(2) - \{\} = \{1,2,7,8,9,10\}$, $U(\phi,2) = H_2(2) - N(\phi) - N(N(2) \bigcap N(\phi) = \{3,4,5\}$. Select a node that belongs to $B(\phi,2)$ and covers maximum number of node in $U(\phi,2)$. Because $|N_{0\to}(1) \bigcap U(\phi,2)| = |\{3,5\}| = 2$ and $N(1) \bigcap U(\phi,2) = U(\phi,2)$, we will get $F(2) = \{1\}$ and $D_{2 \to B(\phi,2)} = \{0,1,2,3\}$. In node 1, we will get $B(2,1) = N(1) - N(2)$ $= \{1,2,3,4,5,9,10\} - \{1,2,7,8,9,10\} = \{3,4,5\}$, $U(2,1) = H_2(1) - N(2) - N(N(2) \bigcap N(1))$

4 Simulation and Evaluation

To evaluate propose algorithm, we considered 1000×1000 array with 20, 40, 60, 80, 100 nodes and nodes distributed equally.

- number of forwarding nodes
- average number of forwarding nodes per antenna element
- number of redundancy messages per node

The experiments carried with NS-2 simulator and we programmed PDP and DPDP module with C++ and Tcl/Tk. For convinience, we do not consider MAC and physical layer.

We tested in case K(=number of antennas per node)=1, 4, 8 and do not consider node's mobility.

Fig. 4 shows number of forwarding nodes that selected via DPDP algorithm. In case of using directional antenna increases number of used antennas rather than K=1, that is, omnidirectional antenna, but the difference is within 5. This is caused by algorithm 3.1 that the algorithm select node which covering the maximum number of neighbor node per antenna element. As number of antennas increase, the number of forwarding nodes increases but the difference is not considerable.

Fig. 5 shows the number of forwarding nodes per antenna, that is, number of forwarding nodes divideded by K. It means interference rate, power consumption indirectly. As K larger, decrease number of forwarding nodes, so the performance is enhanced. And it also reduces ACK implosion problem[10].

As K goes bigger, the difference of number of nodes are larger. For example, in case of K=4, 8, the difference goes to 230% than K=1. It means that DPDP is profitable for directional antennas in the mobile ad-hoc network.

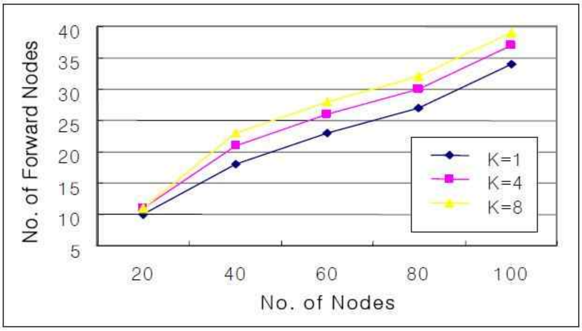

Fig. 4. Relation of No. of nodes and No. of Forward nodes

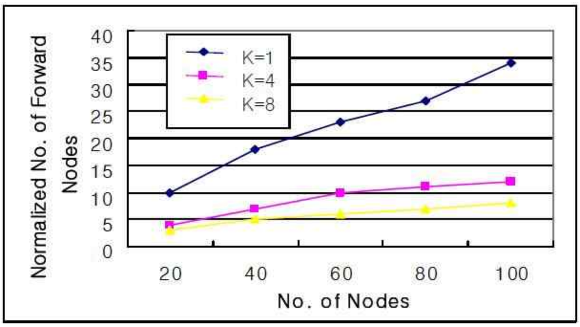

Fig. 5. No. of forwarde nodes per antenna element

Fig. 7 shows the number of redundancy messages, and in case K=8, redundancy messages occur under 2. In case of K>1, nodes receive message from fixed direction as compare to K=1(omnidirectional antenna), so K goes bigger, the duplication ratio gets smaller.

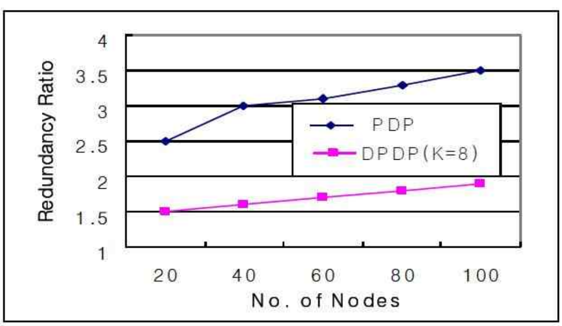

Fig. 6. Redundancy ratio per node

In case K=8, the duplication ratio reduced 160%~190%. As a sumulation result, our algorithm proved that superior than legacy algorithm in many aspect and very useful.

5 Conclusion

In this paper, we proposed directional partial dominant pruning that expanded version of PDP which reduces not only number of antenna elements but also number of forwarding nodes. By simulation, we proved that our algorithm is superior than legacy PDP from the viewpoint of reducing number of nodes and antenna elements. So the algorithm select a node p where $Max(|Ni^{\rightarrow}(p) \cap U(u,v)|)$, $p \in B(u,v)$ that covers q where $q \in U(u,v)$ preferentially. And to reduce redundancy messages, the algorithm found antenna element set $Dv \rightarrow B(u,v)$. As a sumulation result, our algorithm proved that superior than legacy algorithm in many aspect and very useful.

Finally, the research that allows node's mobility and using MAC layer is required.

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