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Secure and Efficient Multipath Routing Using Overlay Nodes

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Abstract— Wireless network consists of intermittently connected nodes which forms clusters with nearest neighboring nodes. Over such networks it is well-known that traditional routing algorithms perform very poorly because every node in network participates in routing decision. To provide optimal multipath routing, such that only subset of nodes involve in routing decisions to bifurcate traffic to achieve maximum throughput. In this paper, we propose a overlay architecture for multipath routing such that only few nodes involved in network to make dynamic routing decisions. For that we focus on two aspects. First, overlay node placement algorithm is developed to choose a subset of nodes (overlay nodes) and prove that only few nodes are sufficient to achieve maximum throughput of network. Second, dynamic routing policy (OBP) is proposed which apply on overlay nodes which splits traffic to route packets on multi paths. The proposed overlay architecture and routing algorithm implemented on NetBeans-IDE using java as programming language. Experimental results show that our proposed algorithm provides better throughput and reduced delay compared to existing backpressure routing technique.

Keywords--- Geo Wireless Network, Backpressure Routing, Overlay nodes, Throughput

I. INTRODUCTION

We study optimal routing in networks where some legacy nodes are replaced with overlay nodes. While the legacy nodes perform only forwarding on pre-specified paths, the overlay nodes are able to dynamically route packets. Routing in cluster based wireless networks consists of two types of traffic: intra-cluster (i.e., two nodes communicate with each other in same cluster) and inter-cluster (two nodes communicate with each other in distinct clusters). The delay of the network increases when nodes are intermittently connected results in the non-availability of routes at each time. In Traditional Backpressure routing, every node in the network involves in routing decisions leading to maintain queues at each node in the network as a result of network size increases. Further, when source and destination are in different clusters, the length of queues increases at each node along its path**.** In wireless network, the performance of queue-based algorithms can be very poor. Instead of all nodes are controllable, we assume that only a subset of the nodes are controllable; these nodes form a network overlay. The choice of the overlay nodes is shown to determine the throughput region of the network. A first finding is that ring networks require exactly 3 controllable (overlay) nodes to enable the same throughput region as when all nodes are controllable, independent of the total number of nodes in the network. Motivated by this we evaluate our algorithm on wireless networks, proposed a optimal node placement algorithm to choose the subset of nodes (controllable nodes), only this controllable nodes are sufficient to achieve maximum throughput, thus reducing number of queues in network. Finally, we propose a heuristic policy which splits traffic to forward packets on multipaths; using congestion information in to account, policy chooses number of packets to be sent to outgoing neighbors based on edge rate. As a results queue lengths can be reduced at overlay nodes along its path.

Section I consists of introduction of the paper, Section II contain related work, Section III contain existing system, Section IV contain proposed system, Section V contain system architecture, Section VI contain methodology, Section VII contain results and analysis, Section VIII contain conclusion and future work.

II. RELATED WORK

Backpressure (BP) routing [2] is a throughput optimal routing policy combined with congestion control, where all nodes are dynamically controllable and implement the backpressure policy across all nodes uniformly. The Optimality of BP is that congestion information propagates through the network via queue backlogs. Applying backpressure at overlay nodes does not find any congestion occurring on internal nodes results in loss of throughput. The problem of delay reduction for back-pressure algorithm has been studied in [2], [6], [10]. The work in [5] considers the problem of setting link weights provided to the Open Shortest Path First (OSPF) routing protocol such that, when coupled with bifurcating traffic equally among shortest paths, the network achieves multi-commodity network throughput. A new throughput optimal policy called Link state routing protocol [4] which uses entropy maximization framework which splits traffic for each destination among its outgoing links with an exponential penalty on longer paths. All these existing techniques require centralized control, universal adoption by all network nodes, or both; thus none of these techniques are not suitable for routing in wireless networks. Two-level Back-Pressure with Source-Routing algorithm (BP+SR) proposed for cluster-based wireless networks has been first studied in [8], but it has large queue lengths at all nodes along a path. Overlay Architecture for multipath routing [1] to route packets on multi-paths, while apply routing decisions on controllable , but it is apply on random graphs and not implemented on wireless networks.

III. EXISTING SYSTEM

Wireless network consists of clusters of nodes, to route packets to destination each node in the network involves in routing decisions. Thus, each node maintains queues at each destination leads to network scales in size. On the other hand, to forward packets from one node to another node in distinct cluster, queue length increases at all nodes in network. Paper [1] proposed An Overlay Architecture for Multipath Routing to choose overlay nodes, but it is not applied on wireless networks. In this paper, we propose an algorithm for choosing the placement of controllable nodes at each cluster of wireless networks, where our goal here is to allocate the minimum number of controllable nodes in each cluster such that the full network stability region is available. Second, we also wish to develop an optimal routing policy that operates on controllable nodes to route packets.

IV. PROPOSED SYSTEM

Proposed an optimal node placement algorithm to identify a minimal set of controllable nodes $V \subseteq N$ in each cluster such that only controllable nodes can interact with access points of cluster which connects with mobile carriers to carry packets to destination which is in another cluster, and the internal nodes just forward packets to nearest controllable nodes. We show that few nodes in a network are sufficient to achieve maximum throughput. It is not possible to directly compare the throughput region of the network when all nodes involved in network with only controllable nodes involved in network. To compare the network throughput, sufficient condition is derived to choose a node as a controllable node. In optimal node placement algorithm, first remove a degree-1 nodes to remove attaches, after that perform constrain pruning on destination trees to minimize the allocation of controllable nodes and choose a placement of controllable nodes and it must satisfy all paths condition. Finally, proposed a heuristic policy operates only at controllable nodes V. These controllable nodes are connected by “tunnels” or paths through uncontrollable sections of the network, where the control policy can choose when to send packets into a tunnel using congestion information in to account and it provides better throughput and delay compared to backpressure routing algorithm.

V. SYSTEM ARCHITECTURE

A wireless network consisting of multiple clusters, where each cluster C_i is represented by a graph $G_{Ci} = (N_{Ci}, L_{Ci})$, where N_{Ci} is the set of nodes in C_i and L_{Ci} is the set of links. The clusters are geographically separated and are connected by a set of mobile carrier nodes M which connects with access point of each cluster. By using Markov process mobile carriers move around to carry packets from one cluster to another. Two nodes in distinct clusters cannot communicate with each other directly. First, they can interact with nearest controllable node which connects with access points, a node in one cluster can interact with other node in distinct cluster through mobile carries. By using optimal node placement algorithm controllable nodes are chosen which operates in a network overlay on top of a wireless network. Nodes that cannot communicate with the access points directly are named as internal nodes; they just forward packets on pre-specified paths only. Thus, the overlay network G = (V, E) consisting of controllable nodes (overlay nodes) V and tunnels E which corresponds to paths (in the underlay network) between controllable nodes and physically packets are stored at different internal nodes along the tunnel. To make dynamic routing decisions, implement heuristic routing policy on controllable nodes to route packets to destination.

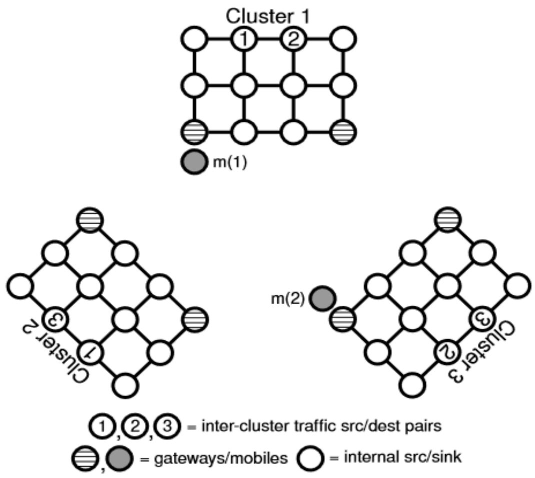

Figure 1. intermittently connected network with three 3×4 clusters

VI. METHODOLOGY

Optimal Node Placement Algorithm:

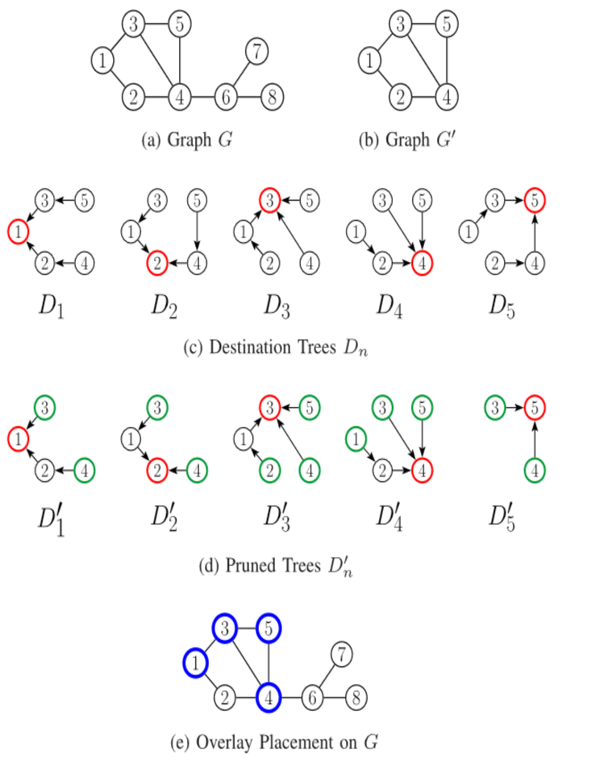

Figure 2. Optimal node placement algorithm implemented on network

Optimal node placement algorithm is implements on wireless network to choose the placement of controllable nodes to make dynamic routing decisions.

Step 1: Remove Degree-1 nodes by removing attached trees, because throughput region does not increase by installing controllable nodes at attached trees.
Step 2: Form destination trees D_n which is used for constrain pruning. The union of shortest-paths P_{SP} x_n to any destination n from all nodes x ∈N \n forms destination tree Dn.
Step 3: Perform constrain pruning at each destination tree Dn to minimize the allocation of controllable nodes in the network. We prune destination trees Dn at nodes x with degree less in Dn than in G to obtain pruned trees Dn.
Step 4: Consider the following binary program to place the minimum number of overlay nodes to satisfy Lemma 2 for all nodes on all pruned trees Dn:

$$V_4^* = \min \sum_n V_n$$

$$s.t. \sum_{a \in \{P_{bn}^{SP}\} \setminus n} V_a \geq 1, \quad \forall b \in \text{Leaf Nodes}(D_n^1), \forall n$$

$$V_n \in \{0,1\}, \forall n \qquad (P1)$$

The placement determined by the solution of P4 satisfies the all-paths condition. That means at least one overlay node is placed from all leaf nodes of pruned trees Dn to node N and we choose a node as a controllable node it can satisfy all paths condition.

Lemma 2: If the degree of node x on tree Dn is less than the degree of x on graph G^1, and there is no overlay node along the shortest path from x to n, then the all-paths condition C.1 is not satisfied.

All Paths Condition

A set of controllable nodes V is said to satisfy the all-paths condition if $P(V)=P_G$. The condition requires the formation of all acyclic paths in a network. Since some of the paths are already given (in our paper PSP), to satisfy the condition, a set of nodes V must enable all missing paths $P_G \setminus P^{SP}$ by path concatenations. The following result establishes that this condition is necessary and sufficient for $\Lambda_G(V)=\Lambda_G$.

Overlay Backpressure Heuristic Algorithm:

We propose a heuristic scheme; this policy takes tunnel congestion into account. At each overlay node, policy chooses the number of packets sent to outgoing neighbors subject to the edge rate constraint.

Step 1: Define the differential backlog for each link (a, b) to find congestion in both overlay and underlay nodes.

$$W_{vw}^c(t) = Q_v^c(t) - Q_w^c(t) - F_{vw}^c(t) \quad , \quad \forall (v,w) \in \mathcal{E}, \forall c \in N$$

Step 2: Define commodity that maximizes this weight

$$c_{vw}^*(t) \in \text{Argmax}_{c \in N} W_{vw}^c, \forall (v, w) \in \mathcal{E}$$

Step 3: Define service function at each overlay node to find the number of packets to be sent to outgoing neighbors subject to the edge rate constraint.
The Heuristic policy chooses

$$\mu_{ab}^{c_{ab}^*}(t, OBP) = R_{ab} \text{ if } W_{ab}^{c_{ab}^*} > 0, \text{ otherwise } 0.$$

Where $\mu_{vw}^c(t, OBP) = 0, \forall c \neq c_{vw}^*$

Intuitively, this policy takes into account both the packet accumulation at the neighbor overlay node v, as well as any packets-in-flight on the path P_{vw}, in the form of negative pressure.

VII. RESULTS AND ANALYSIS

Results show that the proposed algorithm provides better performance compared to traditional backpressure routing algorithm in terms of throughput and delay.

Fig. 3 shows results of the overlay node placement algorithm on wireless network with N = 20, where X-axis represents the edge range and Y-axis represents the fraction of nodes. We see in Fig. 3 number of overlay nodes changes every time with changes in edge range of the network. At edge range r=0.8, the number of overlay nodes reaches the number of nodes in a network. As a result the number of overlay nodes, V, placed by our algorithm grows much faster than the size of the largest connected component.

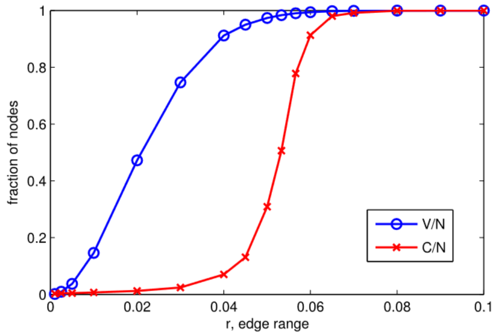

Figure 3. Number of Overlay Nodes and connected components in the Network

In traditional backpressure routing, each node can optimally route packets only on the observation of neighbor backlog to avoid congestion. In our setting, BP apply only at controllable nodes, congestion information is not propagated at internal nodes. As a result, the queue size of BP at overlay nodes is increased dramatically than the queue size of BP. Fig. 4 shows that with the increase of system load, network queue size increases more when BP applied on overlay nodes compared to BP applied on all nodes in a network. When system load p=0.6, queue size of the network increases to 2000 BP applied at overlay nodes.

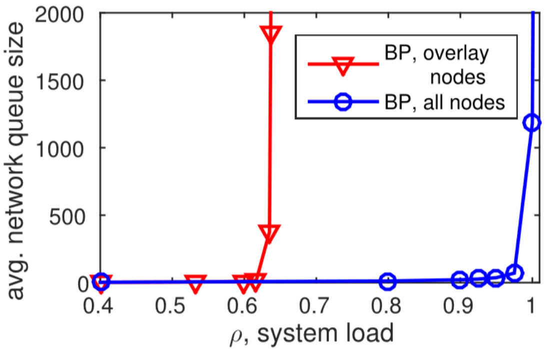

Figure 4. Insufficiency of Backpressure routing at Controllable nodes

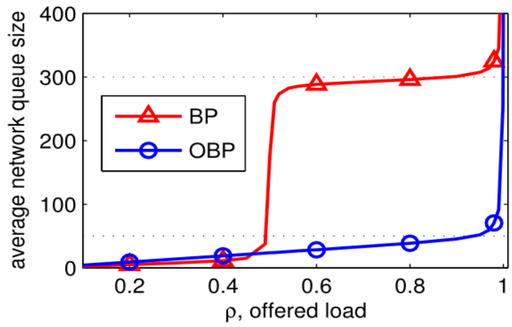

Figure 5. Delay comparison of OBP with BP when offered load changes

In Fig. 5, delay is compared between BP and OBP for a fixed offered load. We observe BP on a cluster based wireless network, per-node queues grow linearly when the offered load is high, however, in OBP policy, we observe the linear growth of per-node queues only at controllable nodes, implying smaller total network queues size and improved delay performance when there are few controllable nodes.

VIII. CONCLUSION AND FUTURE WORK

To provide optimal multipath routing in cluster-based wireless networks, proposed a Optimal Node Placement Algorithm to choose controllable nodes, only controllable nodes can forward for achieving throughput region of the network. Finally, proposed a Heuristic routing policy which can be applied only on controllable nodes provides better throughput and reduced the size of the queues, thereby reducing the end-to-end delay compared to backpressure routing algorithm.

All paths condition is sufficient in node placement algorithm for choosing the minimum number of controllable nodes, but this condition over allocates controllable nodes in wireless networks. Future work may include study of necessary condition for overlay node placement to choose the controllable nodes in a wireless network.

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