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POWER AWARE ROUTING OPTIMIZATION: AN ENHANCEMENT

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Abstract: *PARO, a power-aware routing optimization mechanism, is proposed in [1] to minimize the transmission power needed to forward packets between wireless devices in ad hoc network. The mechanism works by redirecting the route to pass through one or more intermediate nodes on behalf on source-destination pairs, then reducing the end-to-end transmission power. This paper will show an extension of this model and provide an analysis of the geometrical area lying between source and destination in which the intermediate node elects to perform redirection. The duration the intermediate node stays in that area is also computed*

INTRODUCTION:

Power consumption and node mobility are one of the most important characteristics of ad hoc networks and have been under intensive study on recent published papers [1] [3] [4]. The common principle of these research works is to propose network topologies, routing algorithms to achieve the goals of reducing power consumption of devices and adapting with unpredictable network topology changes. Due to such changes, the route can be optimal in term of transmission power at this time but become outdated later, therefore, getting up-to-date information about the nodes to quickly response with changes is desirable.

Power Aware Routing Optimization-PARO is considered as power-efficient routing mechanism for ad hoc networks while concerning with network topology changes. Motivated by the fact that power transmission needed to communication between two radios attenuates proportional to exponent of distance, PARO aims at optimizing aggregate route transmission power as it keeps looking for one or more intermediate nodes between a source-destination pair of communication so the route can be redirected over that intermediate nodes. Figure 1 shows the geometrical view of the process: the link AB is redirected over the intermediate node C. While adding more nodes to route makes the number of hops involving in forwarding packets increases, the hops are shorter then reducing total transmission power. It is assumed that the nodes can dynamically adjust their transmission power on the basic of packet and the power transmitted between two nodes in a link is the same in both ways i.e. the same from A to B and B to A

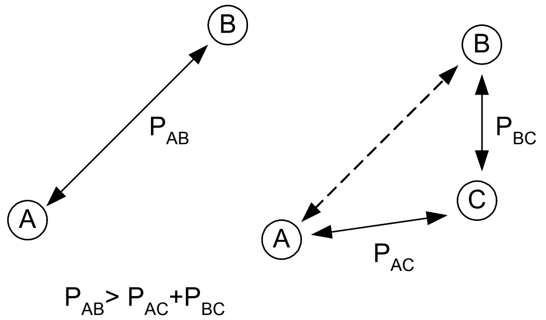

Figure 1: Power optimization model

The central part of PARO is the redirection process. Three nodes including the source, destination nodes and the intermediate node engage in the operation. When intermediate node (node C) travels between nodes pair A and B of communications, it can overhear signals from nodes A and B, it will compute if the route through node C as A⇔C⇔B instead of A⇔B is more efficient in mean of power consumption. Specifically, node C will compute the total energy needed for the link A⇔C and B⇔C and check the satisfaction of this inequality:

$$P_{AB} > P_{AC} + P_{BC} \quad (1)$$

If it satisfied, the new route over node C will be more efficient and node C will implement this redirection process by sending a message to node A and B to announce redirection.

An interesting property of PARO is that all processes are implemented locally; just 3 nodes involving the new route establishment. That certainly saves power and other cost such as bandwidth, delay, and interference for discovering a new optimal route as network topology changes.

However, there is a shortcoming in this mechanism when applying in mobility environment; the question is that should the moving node C makes decision of redirection if it just stays a short period of time satisfying the inequality (1)? If it does, then the network has to pay some higher cost for redirection in comparison with that of keeping the current route. Certainly here there is a tradeoff between the cost of redirection and speed of moving node C

To address such shortcoming, we propose an extended mechanism that regards the movement of node C corresponding to node A and B. In this extension, we assume that nodes are equipped with global position system (GPS) receiver, so that they can easily compute their speeds, movement direction and distance corresponding to other neighbor nodes. We will figure out a geometrical area called relay region (RR) between two nodes A and B of a link in which the node C will satisfy (1). We will verify this region in for different cases depending on feature of power levels of wireless terminals in the network i.e. continuous power level or discrete power level.

BACKGROUND AND ASSUMPTIONS

With GPS receivers, speeds, position, directions of wireless nodes can be computed. We assume that nodes can determine these values without much error. All the nodes are assigned in a 2-dimensional coordinate plane oxy where each node's position will be denoted by its coordinate (x, y) and its speed and movement direction by the vector speed $\vec{v}$. If nodes have positions A=(x_A,y_A), B=(x_B,y_B) then the distance: $AB = sqrt((x_A - x_B)^2 + (y_A - y_B)^2)$. If node A and B move with speeds: $\overrightarrow{v_A}\ and\ \overrightarrow{v_B}$ in directions of angles α_A, α_B to the axis $\overrightarrow{ox}$, the speed of node A corresponding to node B in is $\overrightarrow{v_{AB}} = \overrightarrow{v_A} + \overrightarrow{v_B}$; its absolute value is $v_{AB} = sqrt(v_A^2 + v_B^2 + 2v_A v_B \cos(\alpha_A - \alpha_B))$

The mobility model for ad hoc networks has been thoroughly surveyed in [2]. Several models applied for various scenarios have been investigated. For the simplicity, we choose the Random Direction Mobility Model for our analysis. In this model, the intermediate mobile nodes travel to the edge of a selected area before changing speed and direction. In other words, the they keep their directions and speed during the movement inside the area. By these features, a node in the networks can predict its future position (corresponding to other nodes) relying on its current speed and position. Also, we assume that the nodes attending data transmission in the current route are static.

For wireless link, the signal transmitted at the source with power P_t will attenuate in free space by the exponential of distance r^n, where r is the distance from the radio source and factor n is $4 \geq n \geq 2$. At the short distance the source, n = 2 can be used for simple calculation and analysis. Then the signal power at the point with distance r from the source: $P_r = P_t \frac{\lambda^2 g_t g_r}{(4\pi)^2 r^2}$ (2); where g_t and g_r are gains of antennas.

Once the distance between the receiver and transmitter is known and the limit power level at receiver is specified, the transmitter can compute its appropriate transmission power level i.e. $P_t = P_r \frac{(4\pi)^2 r^2}{\lambda^2 g_t g_r}$

ENHANCEMENT OF PARO

The enhancement model of PARO works by calculating the sojourn time the intermediate node stays in the RR, and all the nodes in ad hoc network nodes must set up their limit values of time in which if the sojourn time of intermediate node in RR is greater that that value, the redirection will be performed, otherwise, it travels through the RR silently. This threshold values depends on various factor likes the power cost of redirecting the route over intermediate node C, redirection delay, signaling…The verification of this value is out of scope of our work..

To verify the RR, we use power inequality (1) and radio transmission model (2). With the aid of GPS and by analyzing data packets, node C can have parameters including distances AB=d_{AB}, AC=d_{AC}, BC=d_{BC} and its moving direction. Antennas gains and other condition can be assumed to be not much different among links AB, AC and BC so we obtain: $d_{AB}^2 > d_{BC}^2 + d_{AC}^2$, which represents the RR. This is a circle area with diameter d_{AB}

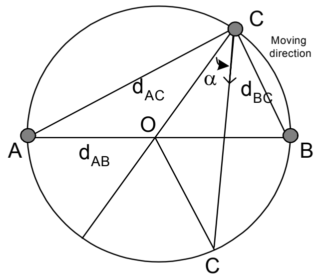

Figure 2: Relay region

Now we compute the sojourn time node C staying in RR. The moving direction of node C can be represented by angle α with respect to a diameter direction of RR from C (or radius CO) as in figure 2. This angle can be drawn from coordinates of node A, B, C and the direction γ of vector speed of node C with respect to axis ox in the coordinate plane oxy as: $\alpha = abs(\gamma - arctg\frac{y_C - (y_B + y_A)/2}{x_C - (x_B + x_A)/2})$.

The length of chord CC' that node C movement intersects RR is: CC'=$2d_{AB}\cos\alpha$; d_{AB} may be computed from d_{AC} and d_{BC} $d_{AB} = sqrt(d_{AC}^2 + d_{AB}^2)$. Then if the speed of C is v, the sojourn time is $\Delta t = (2d_{AB}\cos\alpha)/v$. If the size of RR, and the speed of node C has been known, we can see that the sojourn time is longest if node C travels in a diameter direction i.e. through the central point of RR. Figure 3 displays the sojourn time varying on value of α. Once the sojourn time is computed, node C compares this value to other pre-defined limited value, if it is greater, then the redirection is performed.

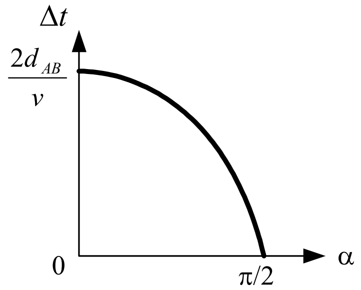

Figure 3: Sojourn time varies on direction

When node C is approaching the edge of the circle area, the route through node C is going to be broken. To avoid the process of discovering and establish a new route, which may be very expensive, node C and its two adjacent A and B have to perform a local route recovery. As node C can anticipate that it will be move out of the RR, it will notify its adjacent nodes A and B in the route. When A and B receive the notifying message from node C, they increase their power transmission levels such that they can communicate directly to each other. With he support of GPS, the distance between A and B is available or easily computed, node A and B can choose the appropriate transmission power levels. After that, the transition from the route ACB to AB is executed. All the processes are in local nodes: A, B and C thus to save power and other cost to establish another new route. Node C can identify the moment reaching the edge of RR by measuring the received power levels from node A and B, or by the distance AC and AB.

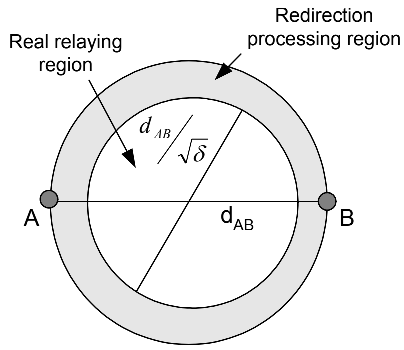

Figure 4: Redirection processing region

For the ease of both entering route and leaving route of node C, we divide the circle area RR to two sections: a smaller circle area concentric to the RR- a real relay region and the arc-shaped area, we call the arc region as *redirection processing region*. When node C moves from outside into this area, it have to determine whether it should enter the route or not, vice verse when move from inside circle to this area, it will prepare to send a notice to nodes A and B that it will leave the route. In mean of leaving the route, this region can be called as unsaved region, as it make the route over node C become soon broken. The size of this area can be selected by choosing the value δ such that $d_{AB}^2 \geq \delta(d_{BC}^2 + d_{AC}^2)$ then the size of the inner circle's diameter is $d_{AB}/\sqrt{\delta}$ and the size of the redirection-processing region is $d_{AB}(1-1/\sqrt{\delta})$. In term of power, node C can find out regions (i.e. arc and the inner circle area) by measuring satisfaction of inequality: $P_{AB} \geq \delta\ (P_{AC} + P_{BC})$ just based on receiving power level and information of data packets coming from node A and B. Value of δ can be chosen depending on the time needed for redirection including time to send signaling messages.

MODEL WITHOUT GPS SUPPORT

Conventionally, wireless devices are not equipped with GPS receivers, nodes then do not know their physical locations and speeds, the original PARO can be applied here as when node C overhears signal from node A and B, it just checks power inequality (1) without considering its sojourn time in RR

Nevertheless, we may base on two-ray propagation model of radio transmission as an illustration of this enhancement model. By this, the distance between source and destination can be obtained relying the power of the direct transmission radio ray and ground-reflected radio ray:

$$d^4 = \frac{P_t g_t g_r h_t^2 h_r^2}{P_r}$$

where P_t is the transmission power from the source and P_r is transmission power received at the destination; h_t, h_r are the heights of transmitter and receiver nodes. The intermediate node analyzes packet information received from nodes A and B to generate the values of distance: AB, AC and BC. From this values, node C can compute the its speed corresponding to node A and B based on distance variations on time: $v_{CA} = \Delta d_{AB} / \Delta t$ and $v_{CB} = \Delta d_{BC} / \Delta t$. Since at the edge of RR, these two speed vectors are perpendicular to each other, then the absolute speed of node C is $v = sqrt(v_{CA}^2 + v_{CB}^2)$. Also the movement direction of node C can be computed by the angle between the vector speed and the circle diameter direction $\alpha = arctg(v_{CB}/v_{CA}) - arctg(d_2/d_1)$. Finally the sojourn time is $\Delta t = (2d_{AB}\cos\alpha)/v$ similar to the previous section

RR FOR DISCRETE POWER LEVEL CASE

We have assumed that all the nodes can varies its transmission power continuously on the minimum power requirement of the receiving side. In fact, the radio devices does not usually have such nice property, instead they can just adjust their transmission power levels according some specific levels. For example, Cisco Aironet 350 wireless cards has only 6 discrete power levels: 1,5,20,30,50,100 mW. Then in some cases, even node C already in RR and satisfying the (1) as described above, the redirection cannot be performed since there are no power levels (lower levels) appropriate for the shorter distance AC and BC. If they keeps the same power levels, the route even have to pay more cost for power, delay… by implementing PARO and passing the route through node C. In other words, if they change their power levels as their available lower levels, the links between these nodes cannot be established since that levels are not enough for receiving sides

For proper working of the model, there is a need to take the discrete power level feature into the computation of RR. Given each node has l levels as P_1, P_2, …, P_l which are similar for all nodes, the conditions for redirection would be:

$$(3)\begin{cases} P_{AB} > P_{AC} + P_{BC} \\ P_{AB} = P_k; P_{AC} = P_i; P_{BC} = P_j \\ 1 \le i, j \le k \end{cases}$$

When C overhear signals from both A and B, the main task node C has to do is to check if there is a lower power level which is enough for links AC and BC and the summation of power for that two links is less than that for link AB

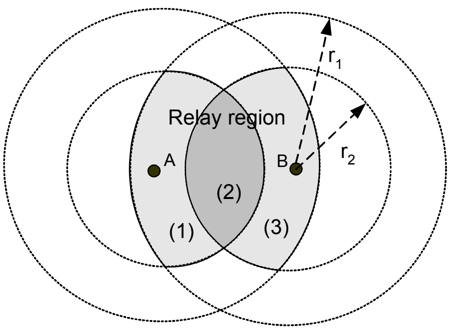

Figure 5: Relay region for discrete power level case

This system of conditions (3) can be presented geographically. Without loss of generality, we suppose that there are only two power levels P_1 and P_2 where $P_2 = P_1/k$ ($k>1$). The transmission ranges of a node corresponding those levels are circles with radius r_1 and r_2 as shown in the figure 5

The RR is not a circle area as in the case power levels are continuous. It is formed by intersection among four different circles (the shaded section) and can be separated into 3 sections numbered by (1), (2), (3). We can see that in section (1) or (3), transmission power level for one link AC or BC respectively is reduced from P_1 to P_2, while in section (2), they are reduced for both links AC and BC.

CONCLUSION:

In this analysis, we have taken a number of assumptions, which may not usually be seen in real ad hoc network, since our purpose is to show how the enhancement model works. We have figured out that in discrete power level scenarios, the mechanism of PARO is not as simple as original one. There are also other issue that the PARO is not always suitable as nodes involving in route redirection have to consider the adjacent nodes in the up and down stream in the route before reducing their transmission power level, otherwise, the route may become broken. In the future work, we will address this issue and consider the stability of this mechanism.

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