Efficient Minimization of Power Consumed for Optimal Energy in Wireless Networks

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Abstract:

Wireless Local Area Networks (WLAN) are being extensively deployed in many places to provide easy access to Internet. Power conservation is a crucial problem in wireless networks knowing that, each wireless node has a limited amount of energy concentrated in a battery.

The main objective of our paper is to use a variable transmission range in order to conservation of energy and to maintaining the connectivity of the wireless nodes. The capability of sending packets of data over short hops helps conserve power. Consequently, a higher transmission power enables wireless nodes to communicate over longer distances. The optimal reception range of a wireless transceiver is not a fixed number. In this paper, we propose power control algorithm to operate in IEEE 802.11 wireless networks. Transmission range plays a major role in determining the reception range. Effective transmission power control is a critical issue in the design and performance of wireless communication.

Keywords: Wireless network, Transmission range, Power control, Efficient energy.

تحقيق الحد الأدنى الكفوء من القوة المستهلكةللطاقةِ المثاليةِ في الشبكاتِ اللاسلكيه

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الخلاصة:

تستخدم الشبكات اللاسلكية المحلية المنتشرة على نطاق واسع في العديد من الاماكن لتوفير سهولة الوصول الى الانترنيت. ان توفير الطاقة هي مشكلة حاسمةفي الشبكات اللاسلكيةمع العلم أنه كل عقدة لاسلكيه تحتوي على كمية محدودة من الطاقة تتركز في البطارية. الهدف الرئيسي من البحث هو استخدام نطاقات نقل متغيره من أجل الحفاظ على الطاقة والحفاظ على الاتصال اللاسلكي. القابلية على إرسال الحزم من البيانات عبر القفزات القصيرة يساعد

على الحفاظ على الطاقة. وبالتالي، فإن القدرة العالية للارسال تتيح للعقداللاسلكيه الاتصال عبر مسافات أطول. في هذا البحث اقترحنا خوارزمية للسيطرة على القدرة في الشبكات اللاسلكية. ومدى الارسال يلعب دورا رئيسيا في تحديد مدى الاستقبال . ان قدرة السيطرة على الارسال الفعالة في نقل الطاقة هي قضية حاسمة في التصميم و الانجاز لأداء الاتصالات اللاسلكية.

1. Introduction:

A wireless network is an autonomous collection of wireless mobile nodes that communicate over bandwidth-constrained wireless links. The network is decentralized and all network activity including topology discovery and message delivery must be executed by the nodes themselves [1].

The users in wireless network are mobile nodes i.e. their location changes from time to time and they communicate with each other by sending messages but they do not require the assistance of an access point [2].

Wireless networks have a dynamic topology, easy deployment strategy, limited bandwidth, limited battery power, lower data rates, higher error rates, higher delay etc. The topology of a wireless network may change rapidly and they may re-organize themselves in an arbitrary fashion. There may be many possible routes available between two nodes over which data can flow, and each path may have different available capacity that may or may not meet the quality of service requirements of the desired service. For a wireless network we can consider many factors which affect the overall performance. These factors are bandwidth, battery power, memory, speed, cost, type of data, delay etc. If the wireless environment is deployed in an area where power is not available in then optimized use of the available battery power is very important for the overall functioning of the wireless environment. A change in network topology may change the distance between the source and destination [3].
Therefore the battery power required to transmit the data from source to destination may also vary since the power consumed is directly proportional to the distance between the source and destination. A node can easily transmit data to a distant node, if it has sufficient battery power. A node transmits its data to other node without any interference, if node lies in its vicinity. A large battery power is required to transmit the data to a node which is situated too far from source node. After few transmissions a node reaches to its threshold battery level and it may exclude from network path. After some time all the nodes may not be available during data transmission and the overall life time of the network may decrease [4].
A key issue in providing cost effective communication for a wireless network is to find a sufficient value of transmission power for each wireless nodes to be able to communicate efficiently with every other node in the wireless network [1].
Though there are protocols that claim to satisfy at least one of the most important network performance improvement metrics, namely, energy conservation or throughput enhancement or network connectivity, there are none that aim to achieve all three goals. Moreover, most of

the approaches are based on specific routing protocols or are dependent on certain underlying mechanisms and fail to deliver as a standalone solution [6].

Consider the problem of power control when nodes are non-homogeneously dispersed in space. In such situations, one seeks to employ per packet power control depending on the source and destination of the packet. This gives rise to a joint problem which involves not only power control but also clustering [4]. However, a lot of energy is wasted this way, since the power is broadcasted towards all directions and therefore attenuates rapidly with distance. It may be therefore advantageous to use directional antennas instead [5]. Based routing protocol for delivering packets in clustered networks whose performance increases with the increasing traffic in the network due to high degree of cooperation among both the nodes and agents. The agents were used to deliver packets where they acted as a messenger that will migrate packets from a source in certain clustered network area to a final destination which is located in different network area [4, 6]. The power consumed by the radio frequency (RF) power amplifier of the network interface card (NIC) is directly proportional to the power of the transmitted signal, and thus it is of great interest to control the signal transmission power to increase the lifetime of mobile wireless nodes [7].

2. Transmission power control in wireless networks:

The transmission power of the transceiver is preset to a default value regardless of the node topology or network conditions. The distance over which the signal can be heard depends upon the value of transmission power [1].

2.1 Trade-offs in power control:

Admittedly, Communication in wireless network is either single hop or multi hop, a longer transmission range reduces the number of hops that a packet needs to transverse in wireless network. A node can transmits or receive data to & from a node which lies in its vicinity. A node can transmit data to a longer distance if it has sufficient energy level. But it also reduces network capacity and effectively increases access delay by increasing the number of nodes that locally compete on the shared channel. It is known that the power required to transmit data from a source to destination node is directly proportional to the distance between the two nodes. Thus for a destination which is located far away from the source, direct transmission of data from source to destination will conserve a tremendous amount of source power [7].

In such cases we have to find an optimal power conservation methodology which can solve this crisis. In contrast, short transmission range allows better frequency reuse and longer battery lifetime. Also, more transmissions can occur in different areas of the network at the same time, thereby improving the network throughput for a shorter transmission range.

Since the power consumed by the radio frequency (RF) power amplifier in a wireless module is directly proportional to the power of the transmitted signal, the node lifetime is greatly increased by lowering the energy required for transmission [3].

2.2 Power control:

The power consumed for data transmission among the nodes is given by the formula:

$$E(d) = ad^{\alpha} + c \qquad \text{..... (1)}$$

Where a is a parameter related to the information, *d* is the distance between two nodes, constant c represents the energy consumption of information processing, and path loss index α relates to the propagation model, usually is set to 2. From **equation (1)** it is clear that as the value of "*d*", the distance between the source and destination increases, the power consumed will increase accordingly. It is also founded that if the number of nodes in between the source and destination are increased, they can be part of the communication between source and destination thus reducing the overall power required for transmission. Consider in following two examples:

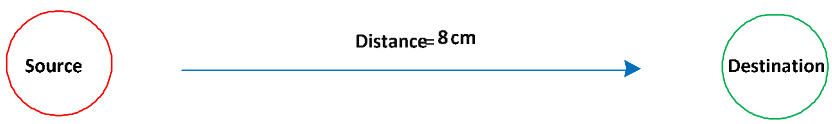

Fig. (1) Transmission from source to destination without intermediate nodes

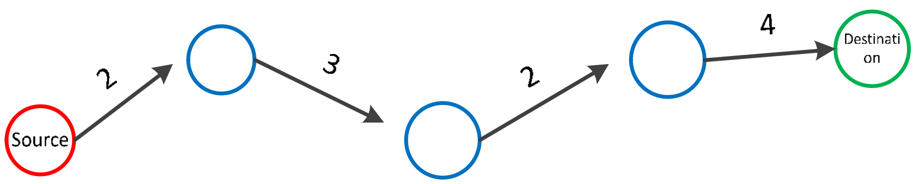

Fig. (2) Transmission of data from source to destination via intermediate nodes

Now, let us analyze the power consumed in both the cases. Let α =2 be the path loss index. Since we consider the same environment and the same information to be passed in both the scenarios, we can consider the values of *a* and *c* to be a constant (k). In the first example the power consumed is $E(d) = 8^2$ + k units (64 + k units).

But in the second example it can easily be found that $E(d) = (2^2 + 3^2 + 2^2 + 4^2) + k$ units is(33 + k) units. Thus it is evident that as the number of intermediate nodes increases, the power consumed at the source will be greatly reduced. It is also of interest that the maximum level of power conservation is achieved with a single intermediate node, if it's placed exactly at the centre of the source and destination. But in actual scenario, all intermediate nodes may not satisfy this principle. Hence we use available intermediate nodes which form a shortest power consumed path with the source and the destination [3].

Moreover, power control affects routing since the ranges of the transmitters depend on the transmit power levels. A further factor to be considered is that power control affects packet end-to-end latency. With small power levels, a packet will take a large number of hops which may linearly increase latency due to the packetization delay at each hop [2].

3. Network topology:

Initially, the topology of wireless networks, each wireless node transmits at a default power level to achieve the maximum transmission range. This range is set to ensure maximum connectivity of nodes [1].

We consider a network topology which is represented by a graph G = (V, E) where V is the set of mobile nodes (|V | =m) and e =(u, v) ϵ E will model wireless link between a pair of node u and v only if they are within wireless range of each other [2].

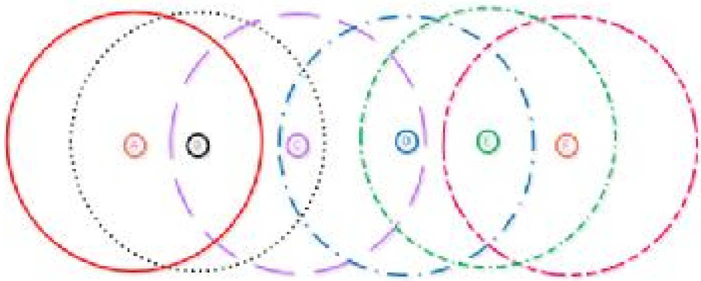

Fig. (3) wireless nodes with maximum transmission range

Figure (3) shows a simple topology of six stationary nodes. Appear, B lies in the transmission radius of A. Hence, B is a neighbor of A.

Similarly, since A and C are within the transmission range of B, they are considered B's neighbors. The neighbor set is set of all single-hop neighbors of node.

The transmission power of all nodes in **Figure(3)** is default value, enabling them to coverage the same maximum radii.

It is obvious that, if A reduces its transmission power to half original value, it is still communicate effectively with neighbor B, shown that in **Figure (4),** consider A and F reduced transmission ranges toan appropriate value [1].

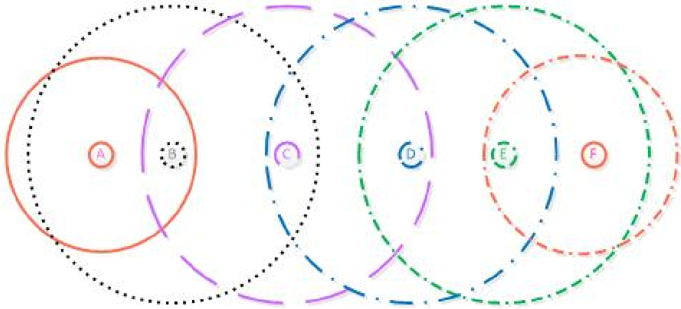

Fig. (4) wireless nodes with variable transmission range

Note that in **Figure (4),** both A and F still Maintain connectivity and neighbors as before. In other hand, two nodes use lesser energy than before, owing to the lower power levels required for the new contracted transmission ranges.

While **Figure.(5)**, considerthree nodes. Node C moves away from A. Suppose that A Knows C's velocity and direction of motion andAupdates transmission range every Δ*t* seconds. Node AExpected the location of C every Δ*t* seconds as shown in **Figure (5)** [1].

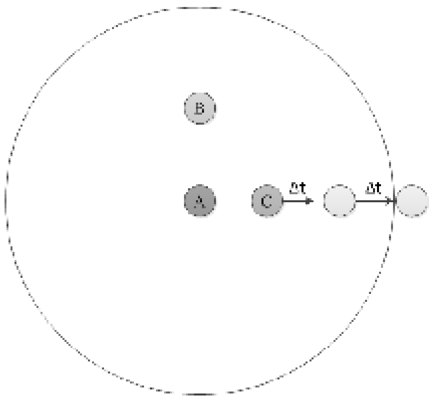

Figure (5) location of C every Δt.

Figure (5) shown Node A's initial transmission range while **Figure (6)** shown updated transmission range of A at t, t + Δt and t + 2Δt.

A has lowered transmission range to cover position 2 of node C. After Δt seconds, node A wants to update its transmission range again, it predicts that C will move out of transmission range in the next Δt seconds. So, A expands its transmission radius to the maximum possible value to accommodate C's movement till C's departure from A's coverage area, as shown in (b). After C has moved out, A contracts the transmission radius to fit only its node B, as shown in (c) [4].

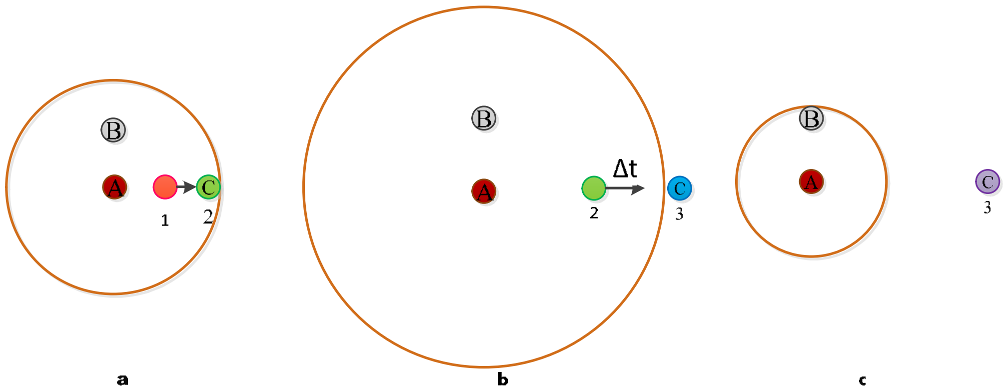

Fig. (6) A's transmission range every Δt.

4. Power control algorithm:

The following steps present the proposed power control algorithm:

Step 1: Each node broadcast data packet with some information about its address, position and timeslot. So, each node will have local information about their neighbors. Initially the transmission range T_r uses the data rate of 54Mbps, which is the IEEE 802.11g standard, and the power corresponding to T_r is PT_r. The transmission range is updated every t_U seconds.

Step 2: Each node deduces the current positions of its neighbors from the most recently received information. It then calculates the distance between itself and its neighbors (d_{ij}) as:

$$d_{ij} = \sqrt{(xi - xj)^2 + (yi - yj)^2} \quad ..... (2)$$

Where (x_i, y_i) and (x_j ,y_j) are the coordinates of the sender and receiver node respectively.

Step3: Each node expected the velocity and direction of motion and calculates the relative velocity of the neighbors.

Step4: Recalculate the distance dE taking into account the speed of the node s_{max} for the time Δt in order to envisage the future position of the node.

$$dE = d + 2 * smax * \Delta t \quad ..... (3)$$

where *dE* represents the effective distance between nodes.

Step5: Calculate the necessary time for the packet arrived to the receiver.

$$t = t_{current} - t_{stamp}$$

Step 6: Choose the maximum distance dE for each node and calculate the corresponding transmission range. Then calculate the transmission power corresponding to that transmission range.

Step 7: Change the transmission power to the calculated power and repeat the process after t_U seconds. If the list of neighbors is empty, then set transmission range to maximum T_{rmax} and the transmission power to the default transmission power P_{Tr}, so in order to have a maximum number of neighbors. Else, set transmission range to the farthest neighbors distance in order to reduce the transmission range by maintaining the sufficient number of neighbors.

5. Simulation Results:

The performance evaluation of the power control algorithm was simulated using MATLAB. The wireless nodes are randomly deployed in a 10 m×10 m area. The number of nodes is varied from 1 to 10 in the simulation, **Figure (7)** shows allocating fixed nodes.

The transmission power is changed every one second. The velocity of nodes is fixed to be 4m/s in the simulation.

The default transmission range is considered to be 250 m as it is in the case of IEEE 802.11 nodes. The power corresponding to the default transmission range is 281.83 mW. **Figure (8)** shows the total energy spent by all wireless nodes in a stationary network as the number of nodes is increased**. Table (1)** shows the optimal nodeenergy of stationary wireless nodes.

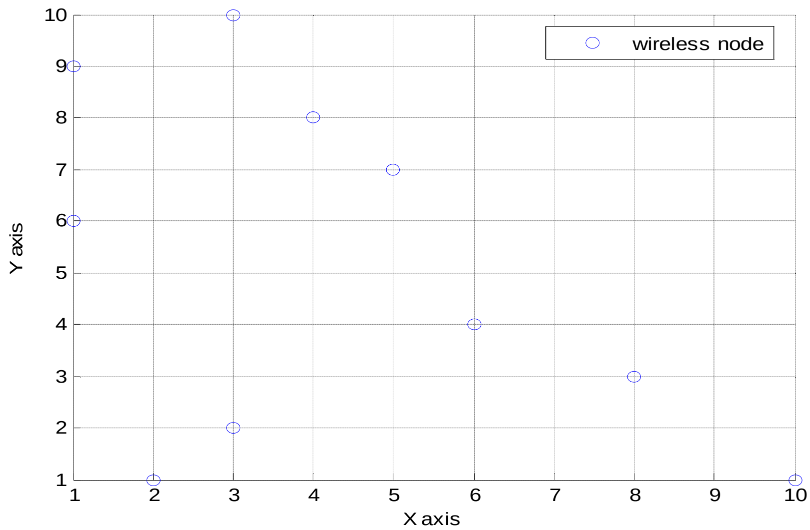

Fig. (7) Distribution offixed wirelessnodes.

Table (1) the values of optimal node energy.

Number of nodes	Energy/nodes	Number of nodes	Energy/nodes
1	(4.1630e-007)*1	6	(1.0e-006 * 0.3723)*2 (1.0e-006 *0.4163)*3 (1.0e-006 *0.2355)*1
2	(1.0e-006 *0.2355)*2	7	(1.0e-006 *0.2355)*3 (1.0e-006 *0.3330)*1 (1.0e-006 * 0.3723)*2 (1.0e-006 *0.4163)*1
3	(1.0e-006 * 0.4163)*3	8	(1.0e-006 *0.1665)*5 (1.0e-006 *0.4163)*3
4	(1.0e-006 *0.4163)*4	9	(1.0e-006 *0.1665)*5 (1.0e-006 *0.3723)*4
5	(1.0e-006 *0.4163)*3 (1.0e-006 *0.2355)*2	10	(1.0e-006 * 0.2355)*3 (1.0e-006 *0.3723)*5 (1.0e-006 *0.4163)*2

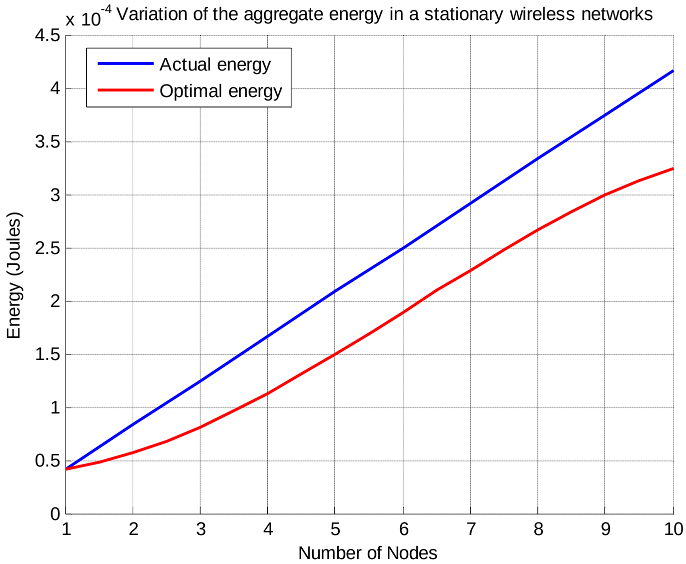

Fig. (8) aggregate energy in fixed wireless nodes.

Figure (8) can be seen that the aggregate energy consumed in the power control approach is less than when the wireless nodes are sending data packets using the conventional fixed transmission power approach. As expected, the energy consumed by the fixed transmission range approach increases linearly with node density.

While as the wireless nodes are moving in and out of the transmission ranges of other nodes. The variation of energy consumption in power control algorithm with the number of nodes in a random mobile network is shown in **Figure (9),** the trend is observed to be similar to that of a stationary network

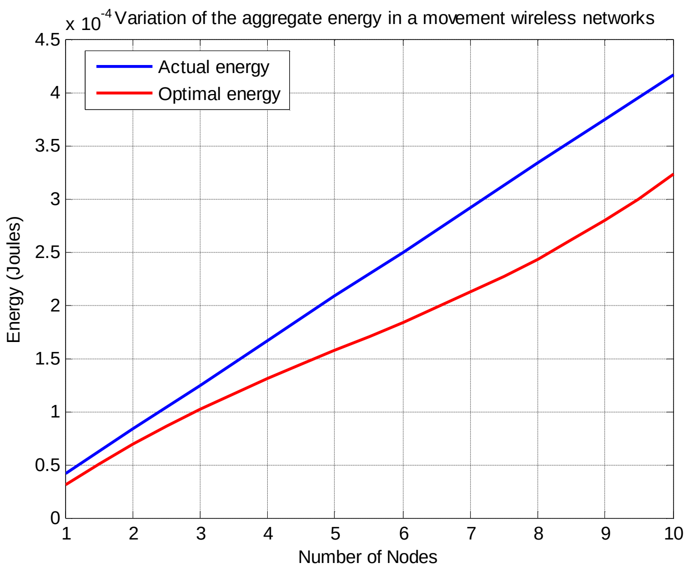

Fig. (9) aggregate energy in mobile wireless nodes.

This is because the network topology at any given instant of time in a stop-and-go wireless network is essentially a stationary snapshot of the wireless nodes between motion. The energy consumption with varying number of nodes at any given instant of time is similar in stationary and mobile networks. It is appear that the energy consumption of the power control approach is lesser than the fixed transmission range approach.

6. Conclusion:

Power Control Algorithm, was based on the variation of the transmission power of the wireless nodes in the network. It was shown that the algorithm supports mobility, preserves connectivity and reduces interference that accrues by other nodes in the network.

This algorithm reduces the energy usage of the nodes compared with other conventional approach that used more than energy while ensuring the same connectivity as the conventional approach

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