INCREASING CONNECTIVITY IN WIRELESS SENSOR NETWORK USING COOPERATIVE TRANSMISSION

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ABSTRACT: The WSN is the enhanced technique used in the field of research using which we can solve many of the problems which are related to remote places. To solve these problems the most important concept is to arrange the nodes into their appropriate positions.\textsuperscript{4} Into the WSN concept we are going to align the sensor into different positions and through the help of sensor we are going to identify the situations. But in a given space we cannot provide the sensor as usual, so we go for the ultimate pattern like sparse technique. In the sparse technique we basically deals with the multi-hop routing technique by using which we can send the information from one node to another node.\textsuperscript{3} But the biggest demerit lies with this arrangement is that, here the loss of connectivity of nodes in the path between source and destination may lead to a partitioning of the network which causes un necessarily wastage of energy and increase of nodes which makes the arrangement more typical.\textsuperscript{11} So, to avoid such problems and to make the operation more effective we present cooperative transmission to connect previously disconnected parts of a network thus overcoming the separation problem of multi-hop network.\textsuperscript{22} By using this mechanism we can provide the effortless data propagation between the source and destination. This also reduces the number of extra nodes and provides the structure more simple and easy to understand.


INTRODUCTION: The traditional Wireless sensor networks are more or less very efficient in the modern programming, but it gains more and more attention as an instrument for fine-granular measuring of a physical parameter in a given area. Typically it is considered as a group of wireless sensor nodes which each contains at least one sensor and a wireless RF communication unit. In the last years, research communities have developed several different wireless sensor network platforms, such as the Motes,\textsuperscript{1} or Smart-Its.\textsuperscript{2} \textsuperscript{3} The sensor nodes are the prime content of the emerging technology.\textsuperscript{4} The sensor nodes are normally distributed over a certain area to give information on relevant physical parameters or events.

The sensor’s measurements taken are then locally interpreted or forwarded to a base-station for further data processing. The broadcast nature of wireless medium has been exploited widely in literature. Without additional transmissions, nodes inside the transmission range of a sender are able to obtain a copy of the packet forwarded to an intended receiver. Dense wireless sensor networks offer the opportunity to develop novel communication and routing techniques based on cooperation among nodes in the neighbourhood. The failure probability of all links is much smaller than that of a single link.

Although there are many previous studies on cooperative communication and routing, most of them focus on physical layer design. Robust routing against path breakage still remains unexplored.\textsuperscript{6} Our main contribution is the investigation of distributed energy efficient robust routing catering to mobile wireless sensor networks. In our proposed protocol, cooperative relay is performed at each hop, so only local knowledge is necessary. Multi-node cooperation involves lower layer coordination. Our robust cooperative routing is based on cross-layer design with MAC layer as the anchor, operated under the IEEE 802.11 MAC protocol.\textsuperscript{7} This random distribution process encounters difficulties when the nodes start to forward their information: it cannot be guaranteed, that a multi-hop connectivity between all nodes and e.g. the access point can be established. The communication range of the nodes will be limited and - depending on the number of nodes in the area (=density) - it is likely that some nodes get isolated as a separated cluster. This can only be avoided by significantly over-provisioning the network by introducing redundancy. Either the radio range or the node density must be significantly increased to ensure good over-all connectivity among the nodes or towards the access point.

SPARSE SETTINGS OF SENSORS: The sparse setting is another important approach by using which the random installation of sensor nodes can be done. By using the above setting we can provide the efficient mobility of the nodes in WSN. I.e., it's not only used in the installation process, but also mobility of the nodes can lead to disadvantageous topologies in a sensor network. Another important process is Clustering and simulations of nodes by using which we control of the system's supervisor and can therefore not be avoided. The following list shortly discusses a few of the most relevant reasons for connections breaks and clustering in a sensor network:
Random Installation Process: The Random process is an arbitrarily arrangement of nodes in a given plane. Here the distribution of the nodes once touched down cannot be precisely predicted. When covering very wide areas with rocks, hills or a forested area, the disturbances for nodes can be various. In this process the changes of getting the error are maximum because the predefine calculation is absent, so the sensors couldn’t predict the exact result. But some nodes might crash during the touchdown process; another might fall into rivers and swim away. Others might land in disadvantageous places with lots of shielding objects around making it impossible to establish a radio communication.

Changes in the Environment: If we change the environment of the arrangement, then we no doubt can get less error, but the arrangement takes greater cost and became difficult to understand. When sensor nodes are deployed in a non-static environment, the connection topology will change over time. Here gaining of thought became more typical.

Wear-out of Sensor in Sparse Arrangement: The wear out is another important concept where the sensor networks are deployed for a long-term monitoring. Here they carry an independent energy source. In this case majority of cases they will be battery-powered, because they won’t have any further source of energy. So the lifetime of a single node is limited through the lifetime of the battery. At the end of the planned lifetime, nodes will start to die out and will no longer be connected to the system.[6]

Mobility of Nodes Sparse Arrangement: It is the technique which defines about the mobility of a node in the WSN. If nodes in a network are mobile and the network is not supported by stationary relays and routers, the connectivity can vary even stronger than in the above described scenarios.[9] In addition to this, the changes will vary quickly over time. Mobile scenarios are e.g. the monitoring of a herd of wild animals, tagging of objects of animals swimming in rivers or seas, ice-colds or any similar effect of natural movement.

COOPERATIVE TRANSMISSION CONCEPT: Form the above, we had found that there are lot of demerits are to be found in the Sparse techniques. Hence we are now moving to the Cooperative transmission technique, which is an ideal means to tackle the threads in the WSN. Using the cooperative transmission, a group of nodes can combine its emission power and achieve a higher emission power as a whole.[8] So the final resulting power consumption is very less as compared to the traditional sparse technique. Here the more nodes cooperatively transmit the higher will the power of the physical medium be.[5] With the higher power, the nodes can reach destinations that are very far away. Figure 1 shows two nodes with their emission range and the emission range of their combination.

Transport Scenarios of sensor in cooperative Transmission: The transport scenario of the respective sensor is more useful when they are considered under the following two categories, such as:

1. Peer to Peer, and
2. Access point scenario.

Access Point Scenario: In the access point scenario we assume that there is an access point in the given network where, the sensor is located in the middle of the sensor field. The sensor has a very high transmit power directly reaching all nodes in the field. The nodes are low-power devices and cannot reach the access point in a single-hop manner.[6] In the access point scenario the exchange of information is always done between the point and the other surrounding nodes.

Peer to Peer Scenario: It is another approach in which the nodes are located as adjacent to each other. In this case the nodes are always consuming less transmitting power as compared to the access point network. Here the exchange of information between nodes in a peer-to-peer manner is not foreseen. Communication with other nodes is only with the intention to relay packets to the access point. In this scenario a node is considered connected if it can forward or route a message towards the access point using whatever technique. The details are as shown in the figure.

In addition to this, here we want to transport information between arbitrary pairs of nodes of the network realizing a mesh connectivity.

Communication Principles in Co-operative Transmission: To compare cooperative transmission to traditional approaches, first of all it is necessary to distinguish between them in terms of their communications principles. If we consider the Sparse settings, then in this case we have to consider the multi-hop communication technique, which is considered as a prime factor of sparse technique. It reaches its capabilities when low node density causes partitioning and clustering of the network.[3] In this situation, cooperative transmission can help to "heal" the broken links. How to take advantage out of the possibilities that cooperative transmission provides is difficult to decide.[2]

The optimal power control for cooperative transmission scheme is e.g. an NP-hard problem.[7] The multi-hop technique is basically operated on the following types of assumption such as:

1. Traditional multi-hop communication (flooding).
2. Wave propagation cooperative transmission.
3. Accumulating cooperative transmission.
4. Ideal hybrid multi-hop cooperative transmission.

In the following above diagram we can see that a node (no. "0") wants to forward a message to a destination (no. "6") using the four different types of communication. Figure 2 shows the reference scenario. Which is the most typical for node 0? So the node 6 could be the access point or an arbitrary peer. Here the node 6 is assumed to be a destination node and the rest are considered as sender. But since the nodes are isolated from each other so it became a typical for the node 0 to carry forward to the task:
1) **Traditional Multi-hop Communication:** The traditional Multi-hop system is the most convenient method used to transmit and communicate the information between the node. Here, in terms of the diagram we are trying to show that how a node can be used to transmit the signal from one node to other nodes. Form the above as shown in figure 2, the node 0 can communicate to node 1 and vice versa. After node 1, the multi-hop communication is finished as the distance to the next nodes is to high. Node 0 can’t find a multi-hop route to node 6 and therefore can’t deliver its message.

2) **Wave Propagation Cooperative Transmission:** It is the approach in which the nodes use the wave propagation cooperative transmission; each node will repeat a received message once. So when the messages are sent the other nodes in the network become active. It will do this together with all other nodes who at the same time received the same message. But here, unfortunately, node 0 can only reach node 1 and therefore the transmission dies out after the second step. So it causes the termination of the process and the network became dead henceforth.

3) **Accumulating Cooperative Transmission:** This is the principal which is the modification of the previous wave propagation cooperative transmission. In this case the Nodes that received a message will not only transmit this message once but several times. We set the number of repeats as a system parameter. This is the technique which is most useful when we are trying to send a number of messages from one node to another node using accumulating process. For the betterment of explanation, let us consider the following figure where, we see the first gains in tackling the problem to deliver a message from node 0 to node 6. Figure 4 shows the situation for the first two steps. After node 0 has delivered the message to node 1, they both repeat the message simultaneously and this cooperative transmission leads to summation of energy (left side in Figure 4). The next two nodes (no. 2 and 3) can be reached. In the then following step, the group of cooperatively transmitting nodes includes the partners no. 0, 1, 2 and 3. Similarly, from the Figure 5 shows the last two steps where node 4 and 5 are included (Accumulated) in the cooperative transmission that finally all nodes except no. 6 transmit cooperatively. The sum of powers is thin enough to finally reach to node 6. For this communication principle, the simple implementation for the wave propagation cooperative transmission also holds: For the delivery and relaying of packets, it is not necessary to keep track of connections and paths. Nodes simply repeat a message several times after the reception.

4) **Hybrid Multi-hop Cooperative Transmission:** This is the modern multi-hop mechanism using which large amount of data is going to be submitted in peer to peer as well as access point scenario. The idea behind this communication principle is to use multi-hop communication wherever possible and cooperative transmission wherever necessary. Depending on the topology of the communication links, this decision whether to choose multi-hop or cooperative transmission for the next communication step can be very hard to decide.

**INCREASING THE COVERAGE:** Let us consider the following table where we have taken some data, We simulated over 20000 random scenarios to illustrate the improvements that can be achieved with cooperative transmission.[5] It is the most advantageous factor of cooperative transmission with which, without loss of generality we restrict the simulations to the access-point scenario.[6] Nodes where uniformly distributed over the whole area, the access point is always positioned in the center of the area.[7]

Table I gives an overview of the technical parameters of the simulation. We simulated different communication principles which are now explained with reference to their names in figures 5 and 4.

The multi-hop scenario like it is used in traditional networks. Nodes forward and relay packets hop by hop. Cooperative caching, sharing and coordination of cached data among multiple nodes can improve the delay and reliability of packet delivery in wireless ad hoc networks. Yin and Cao propose cooperative data, path and hybrid caching,[7] to reduce the query delay and message complexity. In[13] the authors employ cooperative packet caching and shortest multipath routing to reduce packet loss due to frequent route failure and end-to-end delay.

Due to the broadcast nature of wireless medium, neighbouring nodes of a transmitting node can overhear the packet, which is called Wireless Broadcast Advantage (WBA).[20] This is illustrated in Fig. 1. Inherently, it is also cooperative caching in the neighbourhood. As nearby nodes with a copy serve as caches, the next-hop node could retrieve the packet from any of them. Suppose node 1 attempts to deliver a packet to node 5 over path 1–3–5. When 1 transmits to node 3, nodes 2 and 6 may also correctly receive the packet. Cooperation among those nodes may result in high energy-efficiency and robustness when we carefully utilize diversity. In our work, we assume the wireless sensor network is densely deployed, so each node has plenty of neighbors. In our proposed robust cooperative routing protocol (RRP), multiple Accumulated cooperative transmission performs very bad when only few levels are included. The differential (With respect to the node density) improvement in connectivity for the level one version of this principle is very weak. Also the overall connectivity to the access point is bad.

The weak performance of level one is due to the reason that nodes only transmit using their one-hop neighbors ignoring the multi-hop Communication possibilities. Nevertheless, after three levels of this simple communication principle, the multi-hop communication is outperformed when forwarding packets to the access point (See figure 5: “acc. co. tr. 3” performs better than “multi hop”). In figure 4, a very interesting measure is displayed as an example of the advantages that cooperative transmission can contribute: It is the connectivity gain in sparse settings. When approx. 40 Nodes are present using traditional multi hop, only 20% of the peer-to-peer connections are possible. This value cannot be further improved by any routing or other broadcast technique. But when using the new communication principle for the same scenario, over 70% of the peer-to-peer connections are active and can be used for data traffic improving the over-all connectivity by more than 50%! The next interesting measure is the number of nodes necessary to achieve a certain number of nodes to be connected to the access point. This is the question of over-provisioning or redundancy.
If nodes are randomly distributed over a certain area, not all nodes will be connected to the access point.

But if the connection of a certain number of nodes must be guaranteed, then it is necessary to deploy more than the minimum necessary number of nodes. In Figure 6 one can see the number of nodes deployed and the number of nodes that have connection to the access point. The theoretical border is clear: all nodes are connected to the access point. The line of the theoretical border is dotted below 60 nodes, because for our scenarios 60 nodes is the lower limit for a complete coverage of the whole area. For normal multi-hop (and the simulation parameters used in this paper) this number would be 130, meaning a 30% redundancy is necessary. The numbers can be found in Figure 6.

For the same coverage in the same area with the same parameters for communication, the hybrid protocol needs less over-provisioning or redundancy. This will directly reduce the cost when deploying such a system.

Limit Behaviour: The limit behaviour is another important aspect through which we can identify the major problems with the system. For this, we simulated the same scenario using again accumulating cooperative transmission and hybrid cooperative transmission. As we know that the hybrid form is the best case we had considered for the sensor in this case. Here, we simulated different depths of these communication principles to be able to compare the gain that a certain level contributes. In Figure 11 the connectivity graphs for the different protocols and different levels has been showed using which we can easily identify that both protocols reach the same average limit connectivity for a given node density. So if the maximum possible connectivity must be reached in the system, it is finally not a question of the specific protocol. But, the hybrid protocol reaches the limit already in the third level.[3]

It simplifies that the hybrid graph increases as we move forward. So as soon as we reach to the limit the graph is became ideal and steady. So it is the factor which only identifies the situation. The details can be identified with the help of following diagram.

Energy Consumption: As mentioned in the above section, we assume broadcast communication for all packet transport processes with the energy model is not the target of our discussion, rather we focus to mention some general issues here. In general in the Hybrid cooperative transmission, which is the most powerful presented principle – has also the highest energy consumption. This is due to the alternating process of multi-hopping and cooperative transmission.

Since, in the multi-hop process, the next cooperative transmission process will include all connected peers. Therefore the hybrid scheme will double the necessary energy compared to the multi-hop broadcasting. There is a general trade-off between connectivity and energy consumption. The more steps an accumulating or hybrid cooperative transmission scheme runs, the more energy will be consumed.

So if possible then try to reduce the number of sensor nodes in the network, so that we can minimize the energy consumption in a greater extent.

CONCLUSION: From the above discussion, we mainly conclude that, the Cooperative transmission can improve the connectivity of nodes toward other nodes or an access point especially in sparse settings. In general it is assumed that the cooperative transmission takes lesser energy if we had a lesser number of nodes in the arrangement. On the other hand if we took the case of multi hop arrangement, we the different scenario. This new communication principle can overcome connectivity problems in sparse settings or heavily partitioned topologies. Looking back on the limit performance analysis, the hybrid protocol is the one with the fastest convergence towards the optimum. On the other hand, it is much harder to be implemented. Multi-hop communication is instead limited to its one-hop mesh connectivity.

So, from the above discussion we conclude that, the cooperative transmission is very easy and can be stateless and without routing tables or similar connectivity lists. In the usual wireless sensor networks cooperative transmission can also be applied as a fall-back solution only. For that case, the network would perform normal routing, broadcast and multi-hop protocols with the necessary properties. So the cooperative transmission is the most optimal solution for the upcoming WSN problems what are going to arise now a day. So if we go for this arrangement then, it takes lesser space and energy in terms of its implementation, on the other hand its application wise utility will be much higher as compared to other transmission modes.

REFERENCES:
### Table I
**Simulation Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation area</td>
<td>500 m x 500 m = 250,000 m²</td>
</tr>
<tr>
<td>Number of nodes</td>
<td>100</td>
</tr>
<tr>
<td>Average nominal radio range</td>
<td>30 m</td>
</tr>
<tr>
<td>Fading exponent</td>
<td>1/3 = 2</td>
</tr>
<tr>
<td>Topologies for each number of nodes</td>
<td>100</td>
</tr>
</tbody>
</table>

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**Fig. 1.** Increasing the emission range by summation of the radio power.

**Fig. 2.** The communication scenario: node 0 (source) wants to forward a message to node 6 (destination).

**Fig. 3.** The communication scenario using *wave propagation cooperative transmission*.
Fig. 4. The communication scenario using *accumulating cooperative transmission*.

Fig. 5. The communication scenario using *accumulating cooperative transmission*.

Fig. 6. The communication scenario using *hybrid multi-hop cooperative transmission*.

Fig. 11. Limit gain for cooperative transmission.