Poster Abstract: Three Plane Localization

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Abstract

We present a new technique called "Three Plane Localization" to improve the accuracy of many existing range based and range free localization schemes. The key idea is to intentionally create interference at a node by scheduling concurrent transmissions of nearby nodes. Our evaluation on the TinyNode and TelosB platforms confirmed the practicality of the technique and also underlined our theoretical findings.

Categories and Subject Descriptors

C.2.1 [**Computer-Communication Networks**]: Network Architecture and Design,Wireless communication

1. INTRODUCTION

Localization in wireless networks is a well studied topic. Some solutions rely on special hardware, such as the geo positioning systems(GPS), other techniques simply work with the available capabilities of a standard wireless node, such as RSSI measurements or connectivity information[1, 2]. It is also common to have a non-homogenous network, i.e. anchor nodes with known positions and a set of simple nodes of unknown positions. Typically, measurements are noisy (in particular RSSI) and suffer from multipath effects and other issues. Thus, frequently, many measurements using distinct nodes are combined to compute an estimate, e.g. [1] checks for (each set of) three nodes whether a node is within the triangle. Our approach can be used to extend and improve free range and RSSI/LQI based measurement schemes by providing additional information, i.e. measurements.

Though the approaches regarding leveraging RSSI measurements and range free localization differ in many aspects, they all share the fact that only one node transmits at a time (such that collisions are avoided). Though this sounds natural, our idea is to intentionally let multiple nodes transmit concurrently to introduce collisions in the case of range free localization schemes or to create additional RSSI/LQI measurements due to overlapping signals. In the following we focus on free range localization.

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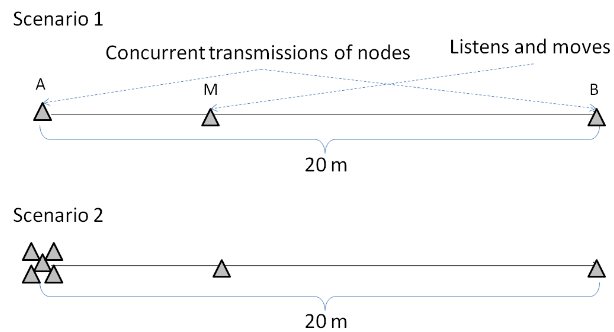

Figure 1: Evaluation scenarios

2. THREE PLANE LOCALIZATION

For illustration consider a simple network consisting of two fixed nodes and a mobile node(such as in Scenario 1 in Figure 1). Assume that all nodes can communicate with each other and we want to (roughly) localize the mobile node M within the network with two nodes A and B of known positions. We do not measure RSSI/LQI but only rely on link quality. With ordinary range free localization techniques, i.e. only using connectivity information to the two depicted nodes in Figure 1, it is only possible to say that node M is within communication range of A or B. Generally, it cannot be deduced whether node M is closer to A or B. To improve on that we explicitly schedule multiple concurrent transmissions. In case both nodes A and B transmit at the same time node M might receive nothing, the message sent by A or the message sent by B. Intuitively, node M receives the message from A, if it is close to A and nothing if it is around the middle of nodes A and B. Thus, when nodes A and B transmit concurrently (a few times), node M can simply count the number of received messages of each node and make an inference about its location based on the collected data. Signal strength decreases quickly with distance, i.e. in the SINR model it is assumed to decrease by the power of 2 to 6 of the distance to the sender. Thus, often (depending also on the hardware) the area where nothing is received is relatively small compared to the area where either a message from A or B is received. Therefore, node M can determine whether it is closer to A or closer to B or close to the middle, i.e. the entire plane is split into three parts. In general, for a large network we can let all pairs transmit. Each pair yields an area of which we know that node M is in it. The intersection of all planes gives a more accurate estimate of the position of node M than conventional free range localization. The idea of computing an intersection (of circles or triangles) has also been used (and studied extensively, e.g.[1]) to improve the quality of localization. Thus, we do not describe it here.

One can also let more than two nodes transmit concurrently in the hope to create additional planes beyond those when letting all pairs of nodes transmit. In principle, if several nodes are perfectly synchronized and transmit exactly at the same time, i.e. interference is constructive, this is the case. Typical transmission frequencies are in the order of 1 Ghz, meaning that the synchronization must be in the nanoseconds range. However, with standard hardware this is a challenge. Let alone the difficulty of synchronization, due to the characteristics of signal strength, i.e. its fast fading with distance, the number of concurrently transmitting nodes must increase significantly to get planes that differ clearly from all planes created by node pairs. Let us go through an example. Assume, that node M is closest to nodes A and B, i.e. say it is at distance $0.4d$ from A and distance $0.6d$ from B (similar to Scenario 1 Figure 1). Assume that either A or B is received, i.e. if M is at distance less than $d(A,B)/2$ node A's message is received, otherwise B's message. Now, we want to have another plane at distance $0.4d$ from A to localize M more precisely by letting more nodes transmit concurrently. We compute an estimate how many (perfectly) synchronized nodes s additionally to B at distance at least $0.6d$ must transmit, such that M does not receive A any more. Assuming a constant power level P for all nodes and the standard SINR model with no noise, i.e. $\frac{P/(0.4d)^\alpha}{(s+1)P/(0.6d)^\alpha} \geq \beta$. Node M receives a message, if the condition is fulfilled, i.e. the ratio is larger than $\beta \geq 1$(We use $\beta = 1$). The parameter α is typically between 2 and 6, e.g. $\alpha = 2$ in free space (in vacuum) and six for larger distances (for nodes not extremely high above the ground). We use four, which accounts for the two ray propagation model. Thus, we get $\frac{P/(0.4d)^\alpha}{(s+1)P/(0.6d)^\alpha} = \frac{(0.6d)^4}{(s+1)(0.4d)^4} = \frac{(0.6)^4}{(s+1)(0.4)^4} \geq 1$. This yields that we need at least $s+1 = 5$ concurrently transmitting nodes to add a plane at distance $0.4d$. To add a plane at distance $0.25d$ would require 81 nodes! Furthermore, letting all kinds of subsets of nodes transmit concurrently is not feasible in practice.

3. EVALUATION

It is essential to verify the theoretical study of three plane localization. Due to the environment, radio and antenna characteristics node M might receive only one of the two nodes A or B much beyond the middle. Additionally, due to multi path effects, messages might be received at unexpected locations leading to wrong position estimates. To check the validity of these potential drawbacks we considered two test scenarios depicted in Figure 1. We used TinyOS 2.1.1.

In the first scenario two TinyNodes 584 A, B are situated at distance about 20m from each other. A node M is moved between the two nodes. Node M always stays in line of sight of both A and B. The indoor hall environment contained some obstacles, e.g. tables, chairs, pillars. Still, without interference there was (very) good connectivity between A and B at least up to 25m distance. We walked from A to B and let both transmit concurrently for 100 times at several positions. We recorded the number of received messages from each node. This was repeated three times. There was a relatively sharp drop-off at about 12m (See Figure 2). The drop-off might be at 12m rather than in the middle, since node B was somewhat higher above the ground or due to the antenna (made of a simple wire) or due to the obstacles that hindered node A more than B. The gap of about 3 m between receiving "almost" all messages from A to almost all from B was not too far from expected, but the behavior within this gap was very unpredictable. Link quality was very sensitive to time (there are other testbeds in the building) as well as location and fluctuated sometimes from one extreme to the other. We also found that the TinyNode had problems in case of vibrations. Therefore, we held the node still when performing measurements. In the second scenario we tested the effect of multiple concurrent transmitting nodes, i.e. we put 4 more nodes next to A and let all five nodes transmitted concurrently. Our findings were similar to Figure 2, i.e. the gap was only a little shifted towards B and did not become much larger. The shift is likely to be attributed to the hardware and position of the individual nodes rather than to their interaction (i.e. constructive interference). For the TelosB platform we focused on scenario 1. We relied on the onboard antenna and used smaller distances for A and B, i.e. 6m. The environment was harsher, i.e. an office room full of obstacles and frequent interference from WLAN. The results were qualitatively the same, but the observed variation in the number of received messages was higher and sensitive to location and time, e.g. even close to A (0.5-1.5 m away) sometimes node M received many messages from B. We attribute this mainly to multi-path effects and the different radio characteristics.

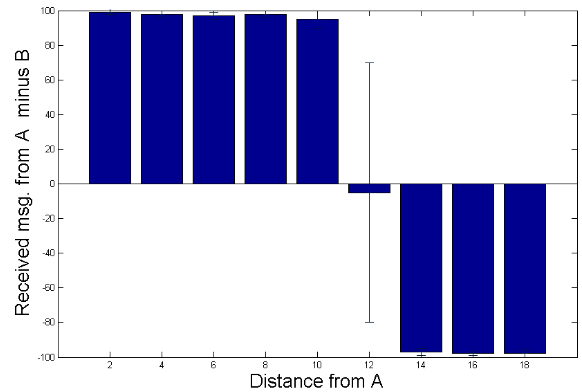

Figure 2: Node M moves from node A to node B. The plot shows the received messages by M from A subtracted by the received messages by M from B. The vertical lines correspond to the standard deviation.

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4. REFERENCES

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