OMESH Networks

OPM15 Application Note: Wireless Location and Tracking

Version: 0.0.1

Date: November 10, 2011

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1.0 Introduction

OPM15 is a large-scale cognitive wireless networking module, providing great flexibility for a wide range of applications. Powered by the OPM optimized radio design and networking stack, the result is a fully integrated module providing a complete system for dynamic wireless networking for real-time and high-performance communications. The module has the following attributes: 1) dynamic drop-and-play (supporting station mobility); 2) real-time communications over unlimited number of wireless hops; 3) low power consumption and small footprint; 4) compatible with the 802.15.4 standard; 5) tolerant of interference in unlicensed spectrum.

This document describes the principles of how to use OPM15 radio for location and tracking by RSSI (Radio Signal Strength Indicator) data.

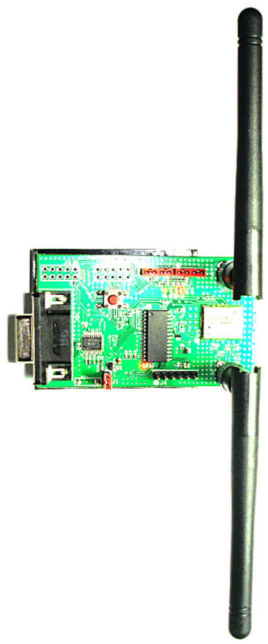


Figure 1–OPM15-E Carrier Board (Dipole Antenna)

2.0 RSSI Data Collection for Location/Tracking

2.1 Query Command

One way to collect RSSI data from neighboring (stationary) OPM15 nodes is by using Query Command on a (mobile) node [1]. When Query Command is called from the MCU, the radio will respond with a Query Response if such responses were previously received and saved in the radio. Otherwise, the radio will broadcast a Query Request. If a neighboring (stationary) node is configured with Query Enable [1], it will respond a Query Response, with certain number of Query Requests being received. A Query Response is composed of: 1) the network address of responding node; 2) the RSSI data and sequence ID (RSSI Record) of certain number of received Query Requests. The MCU of (mobile) node can optionally process the Query Response data; or otherwise send the data to a cloud server (through network gateway) for further processing.

For an OPM15 radio with Query Enable being configured, it can maximally save and respond the RSSI records from 32 distinctive nodes (as differentiated by network address). Therefore, if the number of co-located mobile nodes is larger than 32, the maximum RSSI records to save before responding shall be configured as “one”; or other methods for collecting RSSI data shall be utilized.

2.2 Mobile Broadcasting

Another way of collecting RSSI data is by periodically broadcasting an application protocol packet from mobile nodes. Any stationary nodes that have received the broadcasting can record the RSSI and a time stamp (e.g., sequence ID), and then send the RSSI record to a cloud server for further processing.

Since broadcasting does not have guaranteed delivery, it is recommended to broadcast a few packets consecutively in one shot. The MCU of stationary nodes can use a time-out timer to send (e.g., to a cloud server) all the received RSSI records in one shot from a distinctive mobile address.

2.3 Antenna Position

Antenna position between stationary and mobile nodes is important for RSSI collection. For example, by using the dipole antenna shown in Figure 1, if the stationary nodes are not in the same horizontal plane of mobile nodes, the antennas shall be better horizontally placed, since the vertical radiation of dipole antenna is especially weak.

In the installation of stationary nodes, it can be important to note that the mutual radiation pattern between a stationary node and a mobile node shall be kept similar for all the stationary nodes.

3.0 Location Algorithm

Two location estimation algorithms are described here. For any particular mobile node, it is recommended to only process the RSSI records to three strongest stationary nodes.

3.1 Weighted Total Algorithm

For a mobile node in the system, the closer it is to a stationary node, the bigger RSSI will generate between the stationary node and the mobile node. The weighted total algorithm takes the RSSI values and the coordinates of the stationary node and finds the relative location of the mobile node.

For an omnidirectional antenna, the received power has the following relation with the distance:

$$d \propto 1 / RSSI^{\frac{1}{n}} = K$$

'd' is the distance between the mobile node and the stationary node and 'n' is the fading factor in this room. RSSI is in linear scale. Using this correlation, we can get the relative distance from mobile node to different stationary nodes.

$$\frac{K1}{K2} = \frac{d1}{d2}$$

Then the algorithm will use this relationship as a weighted factor to figure out the location of the mobile node as following:

$$Pmobile = \frac{\left(\frac{1}{d1}\right) \times P1 + \left(\frac{1}{d2}\right) \times P2 + \left(\frac{1}{d3}\right) \times P3}{\frac{1}{d1} + \frac{1}{d2} + \frac{1}{d3}}$$

The algorithm can be further calibrated by the fading factor *n*, and it is very robust to environment change and complex geometry. In a lot of application, it is also better to use only the three stationary nodes with the strongest RSSI in the mobile location estimation.

This algorithm is illustrates in the figure below**:**

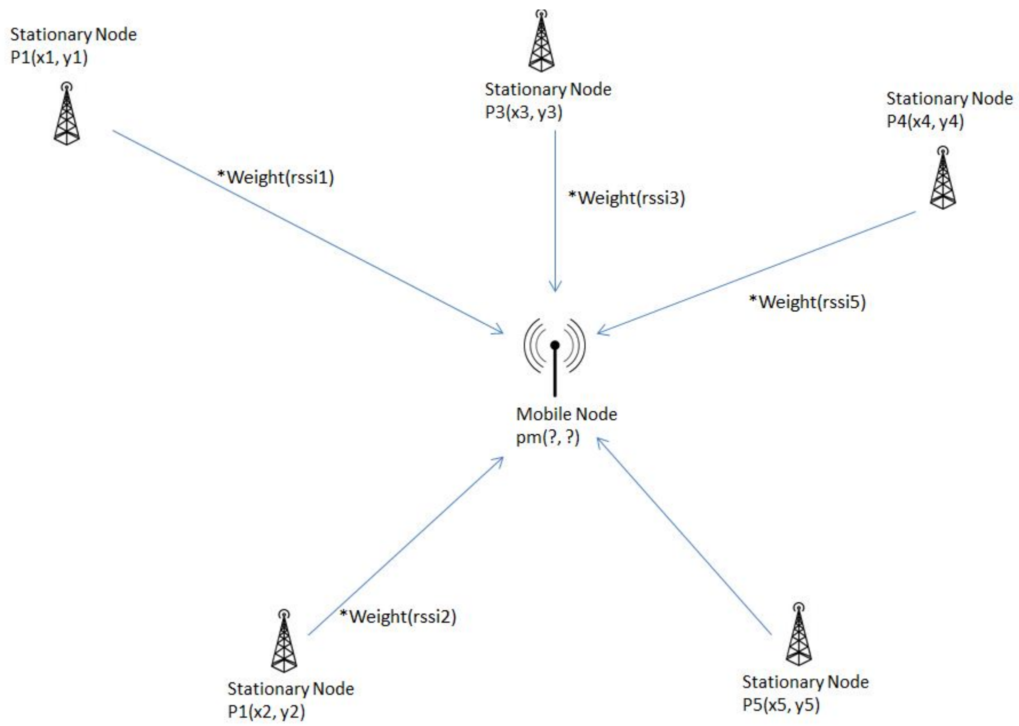


Figure 2–Illustration of Weighted Total Location

3.2 Absolute Distance Algorithm

The distance between mobile node and stationary node can be calculated when a fading factor and a reference RSSI is known. Using a reference RSSI of *A* at 1 meter and fading factor of *n*, we have the following equation:

$$d = \left(\frac{A}{RSSI}\right)^{\frac{1}{n}}$$

Based on the location of any two stationary nodes and the distance between them and the mobile node, we can get two points that satisfy those distances, as long as the distances satisfy the Triangular Inequality. This is shown in the figure below.

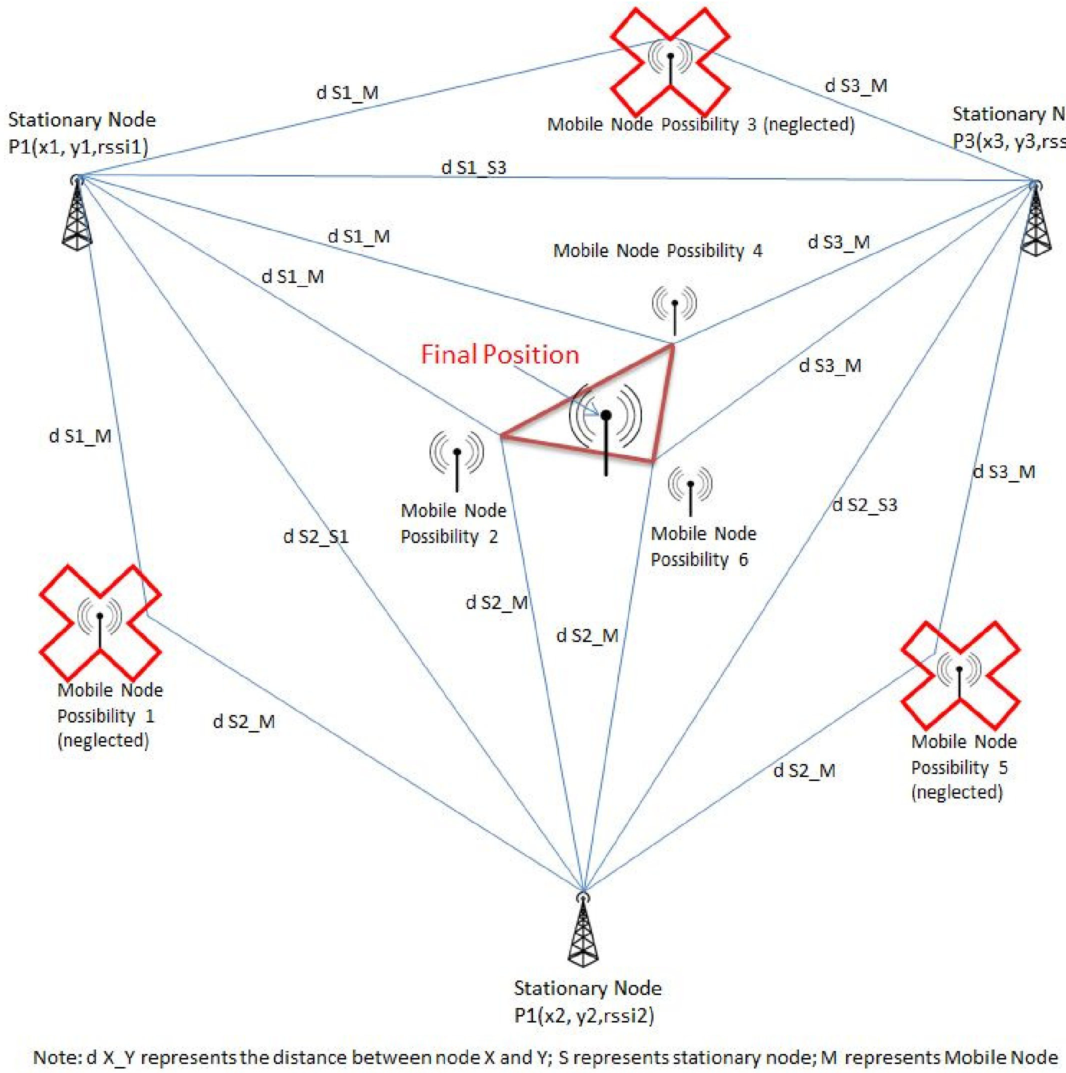


Figure 3–Illustration of Absolute Distance Location

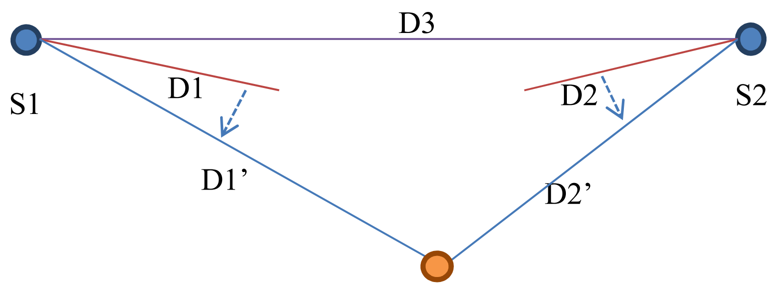
Referring to the figure above, for stationary nodes P1 and P2 with the known distance dS1_M and dS2_M, two possible points of the mobile node can be located: Mobile Node Possibility 1 and Mobile Node Possibility 2. By using the absolute distance, the topology should guarantee that the nearest three nodes around any point will contain the point.

Knowing how to calculate the distance, three stationary nodes in the database with the strongest RSSI signal are chosen, as the stronger the RSSI the more accurate. For each pair of the two stationary nodes chosen, two correlated possible points are calculated. Thus three possible points as a result of three pair of stationary node points can be generated by taking the smallest triangle. At last, an average of the three points is chosen as the desired mobile node location point.

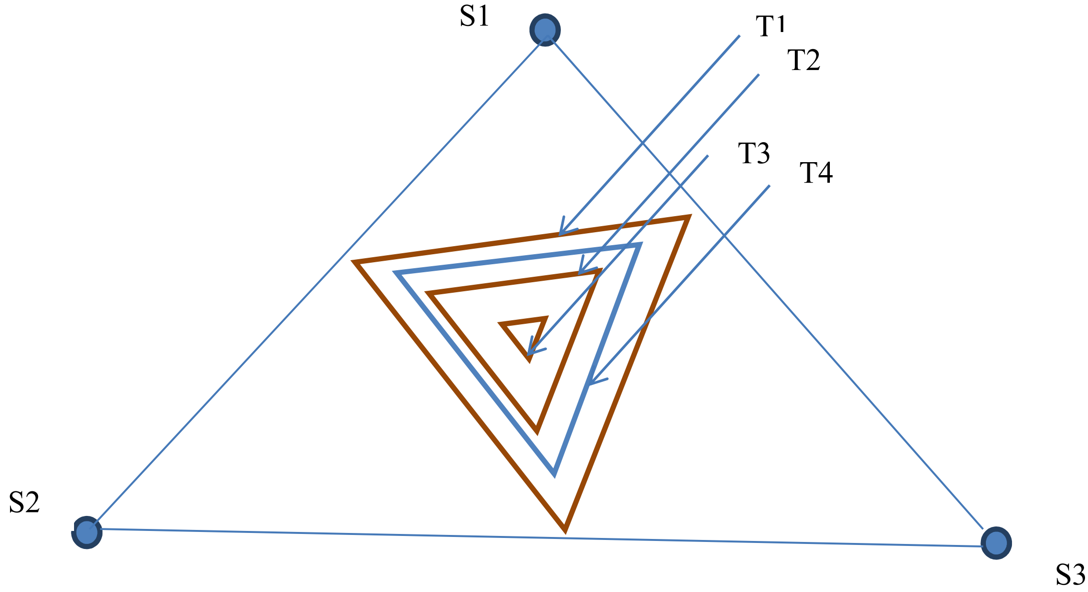
Additional mechanisms are included in the Absolute Distance Algorithm to improve accuracy and solve possible problems.

A triangle can be formed only if the sum of any two sides exceeds the length of the third side. When two stationary nodes are chosen to form a triangle with the mobile node, the Triangular Inequality is not guaranteed. This could happen due to inaccuracy of reference RSSI *A*. If this happens, Triangular Inequality will jump in and increase *A* for a small amount until all three two stationary node pairs will form a triangle with the mobile node.

Referring to the figure below, given *A*, D1 and D2 can be calculated. However, D1+D2 is less than D3, where D3 is the distance between S1 and S2 (the two stationary nodes). In this case, *A* is increased to *A'* as reference RSSI, and results in D1' and D2'. D1' + D2'>D3.



Even when the triangular Inequality is satisfied, the reference is not guaranteed to be the best suitable for the situation. As mentioned previously, three hypothetic mobile node location points can be calculated by the smallest triangle. If the distances are right, the three points should converge. When the three points are the most close with each other, the RSSI reference is the most accurate. This mechanism further increases the RSSI reference to minimize the triangular, which will improve the accuracy.



Referring to the figure above, given three stationary nodes S1, S2 and S3, three possible locations of the mobile node can form a triangle. For illustration, the first triangle T1 has a large area, whereas a smaller triangle is desired to get the best accuracy. The Reference RSSI A is then further increased, so that T1 is shrunk to T2 and then T3. The smallest triangle T4 is used for calculating the mobile node position (for example as the center of T4).

Absolute Distance Algorithm is more accurate when the location of stationary nodes can be accurately mapped and the mobile has line of sight to the three stationary nodes with strongest RSSI. The mobile shall be usually 1 meter away from any stationary node so that near field effect can be precluded.

4.0 Object Tracking

Object tracking is provided when the location algorithm can be run periodically over time given new RSSI records. The estimated location shall be smoothed over time to mitigate any location estimation error. Sophisticated tracking algorithm can be deployed to further predict and filter location estimation based on RSSI scans. The bandwidth of OPM15 radio can support up to 50 scans per second for one mobile node: this is equivalent to supporting mobility up to about 450km/h in around 2.5 meter accuracy.

5.0 Software

Open-source software for Location/Tracking with OPM15 radio network is available from OMESH Networks Inc. (Part# OPM15LOC).

6.0 References

[1] OMESH Networks, "OPM15 Software API Guide", version 3.2.0, available from **http://www.omeshnet.com/omesh**, Oct 10, 2011.