Wi.232DTS and Mesh Networking for short range applications in the US market

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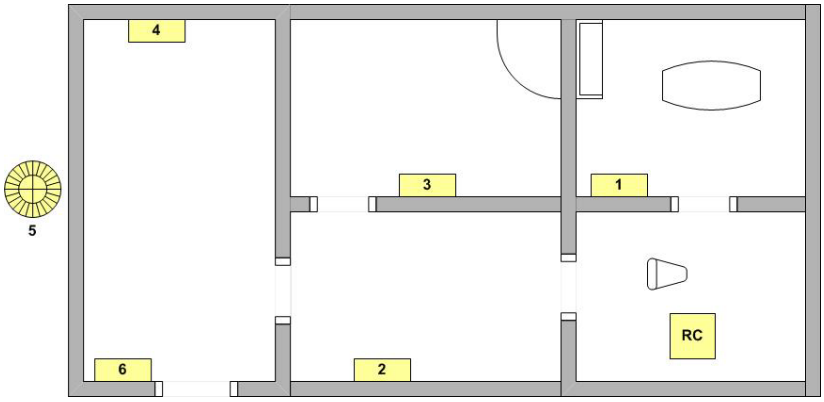
Written by: Steve Montgomery

1. Introduction

Mesh networking has created quite a buzz in the embedded wireless community. It promises self-healing, multi-hop networking capability that lowers node costs and power consumption, and increases reliability in a real-world noisy environment.

In this paper, we are going to examine how mesh networking works and how it competes and compliments our Wi232DTS module. For the purposes of this paper, we have created a very simplistic mesh network example that does not account for least cost-routing or dead-path elimination. These are just two of many routing issues, and there are as many solutions as problems. A Google search will yield numerous references that give an exhaustive treatment of the subjects, so we will not cover them here.

2. An embedded wireless network example



In this very simple example, there are 5 switches (nodes 1,2,3,4,6) and an outdoor light. Each of these “nodes” is equipped with a typical short-range radio link. A user in the lower right room wants to turn that light off with a handheld remote control.

Typical radio circuitry currently available in the market does not have the range to get a message from the remote control to the light. Most of the embedded wireless industry, with a few exceptions, accepts this model (poor RF performance) as the only way to achieve low cost in volume production. We will examine this in more detail later.

For now, let's consider how we can get the message from the remote control to the light. One solution would be to "hop" the message between the nodes in the network until the message reaches node 5.

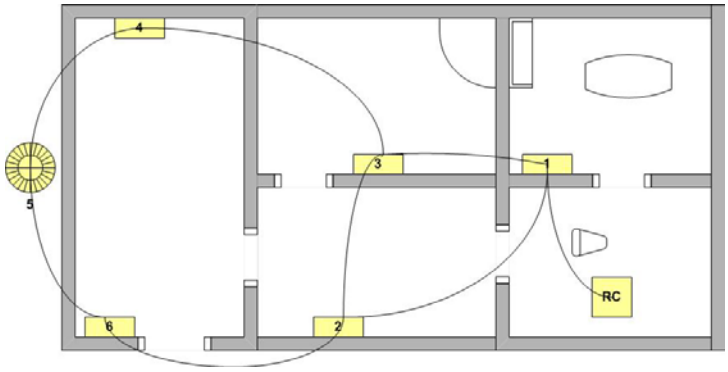
3. Enter mesh networking

Since we can determine which "nodes" in this network are in range of the other "nodes" in the network, we could build a small table into each of the nodes that may look like this:

Node	1	2	3	4	5	6
Table Entry 1	2	1	1	3	4	2
Table Entry 2	3	3	2	5	6	5
Table Entry 3	NA	6	4	NA	NA	NA

We will examine how these tables are created in the next section. For now, let's look at what the table entries mean.

Basically, each table entry is the number of a node that is within range of the node who owns the table. For example, looking at the table, we can tell that nodes 2 and 3 are in range of node 1. If we look at this graphically, we can get a sense of why it is called mesh networking.



In this drawing, each line represents a valid communication path. You can easily see, using this drawing, two different paths from the remote control to the light.

With the tables in place, the actual operation of a mesh network is quite simple. The remote control will send an enumerated message to the light to turn on. How the remote knows that the light is actually node number 5 will be discussed later. For now, let's assume it does. The message traffic will happen like this:

Node 1 receives message from remote control and re-transmits the message to nodes 2 and 3. Nodes 2 and 3 will then transmit the message to nodes 6 and 4,

respectively. Lastly, nodes 6 and 4 will transmit the message, via different paths, to node 5, the light.

Whew! That was a lot of work to turn the light on. What we have just done is to use some reasonably complicated software and a very inefficient communications channel to accomplish the same task that a well-designed wireless solution could accomplish at a lower cost in both power and communications channel efficiency. A simplistic summary could be that we have to use a technology like mesh networking to make up for the lacking performance of the communications hardware in each of the nodes.

Multi-hop routing does extend the range of embedded wireless networks. However, it also introduces multiple failure points into the network. The beauty of mesh networking is that it creates multiple paths within the network between any two points, eliminating the possibility that any single point of failure can prevent communications between those two points.

Now, none of this will work unless we can build the node tables. There are two ways we can do this. Either we can have the user build them manually, which is completely unacceptable, or the nodes can build them automatically.

4. Automatic network discovery

It is actually quite straightforward to build the node tables automatically. The discovery process goes something like this:

Node1 transmits a discovery packet, which is received by nodes 2 and 3. Nodes 2 and 3 respond to the packet, causing node 1 to place their addresses in its table. Then, nodes 2 and 3 each transmit the same discovery packet, and the process repeats as it propagates through the network.

If a really smart and powerful node wanted to map the network, it could send another special command that would propagate through the network causing each node to send its node table. This information could be used for even smarter routing than what we discussed in the last section, but is beyond the scope of the paper, so I will leave it at that.

5. Logical network definition

So it is fairly easy to automatically discover the physical nature of the network, i.e., which nodes can hear which nodes. But how does any particular node get assigned its address? And for that matter, how does the system, a lighting

control system in this case, know which nodes are switches and which are lights? And which light node is the one in the garage?

This “logical network definition” is largely application and product specific. The process by which it is accomplished determines the complexity and cost of the system installation.

In the end, the radio solution, mesh networking or not, has little impact on installation costs. The way the solution is applied, which is determined by the OEM, determines the installation costs.

6. Drawbacks of mesh networking

The benefit of mesh networking is that the range of the network can be extended indefinitely and, assuming multiple paths exist, no single point of failure can prevent communications.

Sounds perfect, right? Well, not exactly. There are some drawbacks that we should consider.

6.1. Cost

First, and most obvious, the complexity of the software required at each node will increase. Cost reductions in RF hardware are offset by cost increases in processing hardware required to deliver the resources and performance required for mesh networking.

6.2. Power efficiency

For battery-powered applications, power efficiency is the most critical specification of a wireless solution. Because mesh networks require the packets to hop redundantly along multiple paths in the network, each packet is sent many times. Every transmission uses precious power from batteries.

6.3. Channel efficiency

Just as every bit transmitted has a power cost, it also has a channel efficiency cost. If the channel sends only one bit for every useful bit information received at the endpoint, the efficiency is 100%. Every bit of overhead reduces this efficiency. Every redundant transmission through the network drastically reduces the channel efficiency.

6.4. Network capacity limitations

A mesh network must operate within a definite capacity. Most current solutions support either 255 or 65,535 total nodes in a network. The more nodes supported, the more resources required on each node and the worse the efficiency of the network. Furthermore, OEMs are forced to fit their applications within the constraints of addressing capabilities of the network, which makes retrofitting mesh networking into existing products very difficult.

7. Wi.232DTS as an alternative in short range applications

The Wi.232DTS module was designed for the same applications that are now being suggested for mesh networking:

- Home automation
- Drive-by and real-time AMR
- Industrial automation
- Wireless sensing
- Toys

7.1. Cost

The Wi.232DTS module is currently the lowest cost total solution on the market. Our networking protocol stack requires far fewer resources than mesh networking, resulting in a lower power, smaller, and less expensive solution.

7.2. Operating range

A typical mesh networking solution has a link budget of 90dB at a data rate of 40kbit/second.

In contrast, the Wi.232DTS module has a link budget of 114dB at a data rate of 152.34kbit/second. Furthermore, the data rate can be reduced to meet the requirements of the application, improving the link budget.

The result is that a solution based on a Wi.232DTS module can achieve the same range that would require 3-4 hops in a typical mesh network.

Because the communications are achieved between the end-points directly, the intermediate hops are eliminated. This results in increased power efficiency and increased channel efficiency.

7.3. Network Capacity

The Wi.232DTS module contains a true MAC layer, which essentially emulates a wired connection. It does not enforce any addressing scheme, allowing rapid integration into existing products and applications, and supporting an unlimited number of nodes.

7.4. Data rate

The increased channel efficiency combined with the high raw data rate available from the Wi.232DTS module yields an impressive effective throughput rate; as high as 115 kbit/second.

For battery-powered applications, this translates to better power performance because the transmitter is on for a shorter period of time.

In drive-by AMR applications, the high effective data rate results in more meter reads per day per van, increasing the ROI for the utility.

8. Wi.232DTS and Mesh Networking

There are, we believe, better alternatives than mesh networking in small, very local network applications. Our Wi.232DTS module is a good alternative.

Even though mesh networking may not be the best solution in very local networks (short range), it offers a lot of promise in applications where the network is spread over a much larger area. A good example of such an application is automated meter reading.

In the AMR application, each electric/water/gas meter on every house in a neighborhood has a built in radio that is used to communicate the data stored in the meter. Data can be retrieved in a number of ways; however, a vehicle driving through the neighborhood most commonly retrieves the data. This system works well and is installed all over the world.

But there is a push, especially with energy meters, to get real-time access to the meter. To achieve this, an access point would have to be installed in a neighborhood that could read all of the meters. The drawback is that the short

range (typically less than 1000 feet) of the radios built into the meters limits the number of houses that could be read by the access point. This metric, the ratio of meters to access point, determines the installation/retrofit cost and ultimately determines the ROI, which is the decision metric used by the utility.

By using mesh networking in that application, the density of meters per access point could be increased by a factor of 50 to 100. Instead of being able to read 10-20 houses per access point, the system could read 500-2000 houses per access point. This is a conservative estimate.

The key to making mesh networking effective in this application is to use a radio solution in each meter and the access point that maximizes data rate and range. The benefits are profound:

- Greater spacing between meters can be supported.
- Fewer dead-spots
- Fewer hops per communication
  - Increased channel efficiency
  - Increased power efficiency
- Higher data rate
  - Shorter on-time resulting in better battery life
  - More reads/day improving ROI
  - Reduced read latency – real time operation

Mesh networking and our Wi.232DTS module are the perfect solution for these types of applications. We can even integrate the mesh networking and application functions right into the Wi.232DTS to create a customized, perfect fit for any embedded application.

9. Conclusion

The Wi.232DTS module is a better solution than mesh networking based alternatives for short range, very local networking applications such as home automation.

Mesh networking will extend the range applications based on the Wi.232DTS module, creating a long range and very robust solution. The combination is excellent for applications that require operation over distances that exceed the range capability of the module.

In both types of applications, using the Wi.232DTS module will decrease system cost and power consumption, and increase data rate and range.

10. Contact Info

Radiotronix Inc
207 Industrial Blvd
Moore, Oklahoma 73160

405-794-7730 phone
405-794-7477 fax

www.radiotronix.com

