Wireless health – Part I: How do we transmit all the data?

How do we transmit all the data?

Please excuse me for introducing another term, 'Wireless', to the plethora of Mobile Health, Connected Health, Telehealth, Telemedicine, Patient Monitoring, and all the others my colleague Paul Williamson explained in his blog post a while ago. But I'd like to focus on the mobility aspect of all the health applications, the reason why we want to make these applications wireless: Patients are rarely stationary. They move from their rooms to treatment rooms or operating theatres and back all the time. People recovering at home are encouraged to go out and exercise but still need to be monitored. Others may just want to have coaching for their daily exercise regime by devices like the one we created for MiLife. All these scenarios have one thing in common: A cable for transmitting the data would be highly cumbersome and impractical. This is where we ideally just cut the cable and the "wireless" aspect comes in. Unfortunately, it is not that simple and a bit of forethought is required before a successful system can be rolled out. I'll be exploring some important aspects of deploying wireless links for medical and health applications via several posts on our wireless medical blog and supplementary articles over the next few weeks. In this first article I'll be looking into wireless patient monitoring solutions for hospitals and the implications of frequency allocations for their reliability.

Wireless patient monitoring is mostly utilized to continuously monitor and record patient's ECG and blood oxygen saturation data. Depending on the system vendor, data are not only used for later evaluation by doctors but also to quickly alert medical staff to any potentially life-threatening anomalies. Being a potentially life-saving device, the patient monitoring system needs to provide high data integrity and low latency.

- Integrity ensures that error-free data always arrives at the monitoring station with a minimum of interruptions. Typical design targets are less than 1 second of interruption in 20 minutes. This less than 0.1% of interruption. For comparison, cellular networks for mobile phones are planned around 5% interruptions. Obviously the exact design target depends on the intended usage of the device and manufacturers may choose to differentiate themselves by defining their individual trade-off on integrity vs. cost and other factors.
- Low latency ensures that data are available in almost real-time to allow for quick responses to any alerts. Latency is actually mandated by the U.S. Food and Drugs Authority (FDA). Typical design targets are less than a few seconds.

Meeting both goals is quite a design challenge as both targets are somewhat conflicting. A crucial choice to make is the employed wireless transmission technology and the frequency band it is used in. The inherent data integrity features of the wireless technology determine how reliable the wireless link will be. Additionally, in some frequency bands other legal users might be interfering with the wireless patient telemetry system.

Throughout the world a range of frequency bands are available for transmitting patient monitoring data. There are multiple kinds of band available:

1. **Industrial, Scientific and Medical (ISM) bands**

   Many of these bands are available throughout the world, often in the same frequency range. Examples of these are the 2400-2500MHz and 5725 to 5875MHz bands which are used for the well-known 802.11b, g, and a Wireless LAN systems or the new 60GHz band.

2. **Wireless Medical Telemetry Services (WMTS) bands**

   These are bands that have been allocated by the United States' FCC for wireless medical telemetry applications. Unfortunately such bands are currently not available anywhere else in the world. Efforts to establish such bands in France are under way. In the U.S. the WMTS bands cover 608-614MHz, 1395-1400MHz, and 1427-1432MHz. Traditionally, the 608-614MHz band has been used but as more systems are rolled out this band is becoming more heavily utilized. So manufacturers of such devices are using the higher two bands, also.

3. **General licensed bands**

   Such bands are allocated on a per-country basis for users applying for a license for a certain frequency band. This is typically done by e.g. operators of mobile phone networks or broadcast services.

4. **White-space bands**

   White-space is an emerging idea where unused bands for television broadcasting are used locally for other services, e.g. broadband internet access. The rules are still very much in flux and medical devices would only ever be a secondary user of a band. Still, it might prove attractive once the required techniques have been developed.

Let me elaborate a bit more on the advantages and disadvantages of the individual bands:

ISM bands

Many ISM bands are available throughout the world. Especially the 2.45GHz and 5GHz bands are available almost universally. This makes using these bands attractive for manufacturers who want to sell or deploy the same device in many different countries. These bands can be used by any device conforming to the rules set by the national and international regulators. See http://www.itu.int/ITU-R/terrestrial/faq/index.html#g013 for some more explanation on regulations for ISM bands. On one hand this is very attractive as few radio-related regulatory issues arise. The manufacturer of the devices still needs to obtain type approval for them. But no licenses are required for operating them. They can just be installed. Also patient monitoring systems can be built upon commercial-of-the-shelf components like Wireless LAN or Bluetooth modules.

The main disadvantage of ISM bands is that many other devices will be using the same band at the same time. Such devices range from a hospital's IT infrastructure to microwave ovens, visitor's laptop computers, smartphones or bluetooth-based headsets. While a hospital can aim to control all electronic devices in its building or even on its campus, the proliferation of personal wireless devices makes this more and more impossible. Also, radio waves do not stop at campus boundaries and building walls. All this can lead to the system working only intermittently, working badly in certain places, e.g. near a faulty microwave oven or even not working well-enough at all. While there are many points in favour of utilising ISM bands, there is no way of guaranteeing a certain performance. It should be said that there are many successful installations of patient telemetry systems utilising ISM bands. They are based on either Wireless LAN or even Bluetooth.

Wireless Medical Telemetry Services (WMTS) bands

The main advantage is the that each installation of a patient telemetry system has its section of the band to itself. No interference from other users of the band can impair the operation of the system. However, the operators of such devices need to coordinate with other users of the band and are only allowed one quarter of the band for one installation.

General Licensed bands

Again, the main advantage is the interference free spectrum which, however, comes at a price. It seems fairly impractical for a single hospital to apply (and pay!) for a license to operate a wireless telemetry system. However, for large companies operating many hospitals and ambulatory treatment centres throughout a country, this may well be feasible.

Conclusions

Now where does that leave you as someone who wants to either design or deploy a patient telemetry system? First of all, you need to know your reliability requirements:

- Do you need extremely low latency for alerting medical staff to potentially life-threatening conditions?
- Do you need 100% accuracy in your data or can you live with occasional drop outs or artefacts in the data?

If you answer yes to these questions, you have little choice but to use a band that is yours alone to avoid outages due to legal interference. In the United States, the obvious choice would be a WMTS band system. In other parts of the world, you would have to apply for a band of your own with the local regulator.

Keep in mind though, that even with a piece of your own frequency spectrum, there still are equipment failures to contend with. So do create a back-up plan and think about the implications and trade-offs between requirements and cost.

If you can live with latencies of more than a few seconds or would be fine with your medical staff identifying outages or artefacts in the data as such, you could be using an ISM band solution. Still, careful planning is required but many have done it and have successfully working installations. I'll be exploring some of the typical installation issues in a future post.

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