**802.15.4k LECIM Channel Characteristics**

1. **Basic Assumptions**
   1. The channel model will only focus on endpoint devices talking to the coordinator (and vice versa), i.e. star topology.
   2. The channel model will not focus on peer to peer communication.
   3. Outdoor propagation is focus with (optional) additional loss due to penetration into underground vaults, etc.
2. **RF Path Loss (see TG4k Hata Channel Model Excel Spreadsheet)**
   1. **General Idea**
      1. Range is the stated goal of the LECIM PHY. As such, PHY proposals will be evaluated in part on the coverage they can get which still supporting the very small bitrate.
      2. Proposed plan is to develop a few “scenario” channel models, e.g. connecting into an underground vault from a cell-tower antenna, connecting to a pad mount transformer from a utility-pole height antenna – and then evaluate the range of different PHY proposals in these different scenarios.
      3. Each scenario will be defined by a particular RF Path Loss profile.  This profile is determined by a number of RF Path Loss line items. These are listed below.
   2. **Penetration Loss (into hard to reach locations)**
      1. Need to quantify the penetration loss into typical underground vaults, indoor sensor locations, and other endpoint locations of interest.
   3. **Shadowing Margin**
      1. 16 dB = 2\*sigma is the nominal shadowing margin that will be used to account for variation in shadowing due to clutter.  See DCN 15-11.0375-00-004k for more details.
   4. **Propagation Loss**
      1. Use different variants of the Hata Model that are valid from 150MHz to 2400MHz to calculate the RF propagation loss.
      2. Three different propagation environments are supported: urban, suburban, and rural/open space.
      3. There is lots of empirical data to back up this model made by respected people and institutions.
      4. See Worksheet 2 of TG4k Hata Channel Model Excel Spreadsheet. More references here: <http://en.wikipedia.org/wiki/Hata_Model_for_Urban_Areas>.
      5. Though technically the Hata Model is only valid up to 2000 MHz.  It has been extended for use in the 2.4 GHz ISM band by many reputable sources, e.g. : Wireless Communications: Principles and Practices, Second Edition, By Rappaport, Prentice Hall, Section 4.10.5.
   5. **Interference**
      1. See the separate section on interference below.
3. **Varied Path Loss between Endpoints**
   1. Since devices will be scattered over a large area, there will be a large variation in the path losses from the collector.
   2. A loss range up to 80 dB between the devices close to the collector and the disadvantaged devices far from the collector is possible.
   3. PHY proposals must be robust to this path loss variability – but that robustness can be left qualitative.  Robustness includes dealing with the near-far problem and potential hidden node problems.
4. **Multipath/Delay Spread**
   1. Multipath exists in any wireless system, but low data rate means long symbols which means delay spread << symbol duration.
   2. Proposed PHY needs to be robust to delay spread up to 5 usec – but that robustness can be left qualitative, e.g. long symbol times for narrowband modulation, RAKE receiver for DSSS, etc.
5. **Coherence Time**
   1. Coherence times for the LECIM channel are similar to stationary cellular channels.
   2. A robust PHY with low data rate will have long symbols, so it will not be expected that the channel is stationary over a PHY packet. Note that PHYs with slower data rates require smaller packets to keep the transmission times reasonably short and that smaller packet durations requires fragmentation of the message. See DCN 15-11.0375-00-004k and DCN 15-11.0395-00-004k for more details.
   3. Each packet should have some protection for this channel variation. But, it will be assumed that packets will be lost due to deep fades. In this case, there should be mechanisms at the MAC (or adaptation) layer to mitigate the loss of packets.
   4. Proposed PHY needs to be robust to coherence time as low as X sec – but that robustness can be left qualitative, e.g. a fragmentation mechanism with interleaved FEC + ARQ.
6. **Interference**
   1. Interference is problem at both the endpoint and collector sites (especially if elevated).  This is particularly true in unlicensed bands. See DCN 15-11-0074-00-004k for more details for the 2.4 GHz band in USA.
   2. Interference is mostly caused from other closely located transmitters in or near the same band.
   3. Channel model will consider co-channel, adjacent channel, and broadband interference sources.
      1. Proposed interference models include 1 MHz broadband noise source with 10 dB Rise over thermal, 100 KHz noise source with 10 dB rise over thermal, 10 KHz noise source with 10 dB rise over thermal, and pulse jammers with a 250 usec duty cycle.
7. **Changing Link Conditions**
   1. TG4K PHY does not need to address mobility (where the endpoint changes during messages), but must address portability (where endpoint moves between messages).  Most endpoints are imagined to be fixed (in a static position) for their lifetime.
   2. Even with a fixed location, the wireless conditions change over time and this needs to be communicated between the collector and the endpoint.  This includes interference, the channel, etc.
   3. PHY proposals should be robust to dynamic wireless conditions – but that robustness can be left qualitative, e.g. adaptation of modulation to changing link conditions, etc.
8. **Transmit Power and Antenna Gain**
   1. Most countries have specific regulations on antenna gain for particular bands.
   2. Depending on the band chosen for a particular PHY, the proposal should be evaluated against the various transmit power regulations around the world.
   3. In general, transmit and receive antennas on both the collector and the endpoint can be different. Note that this will increase the cost of both components.