WHITE PAPER

Emerging IoT Wireless Communication

senaya

ABSTRACT

It is quite apparent by now that cellular technologies, built primarily for voice traffic, cannot currently provide a scalable solution for long-range connectivity for the new world of millions of smart devices, sometimes referred to as the Internet of Things (IoT). Low Power Wireless Area Network (LP_WAN) technologies have emerged as one of the holy-grail technology solutions that can offer the optimal trade-off between long range (>10Km), low power (battery life in multiple years), low cost (<$10 solution cost) and high accuracy (<10m). Senaya has come up with a few potentially disruptive solutions in the LP_WAN space that have the ability to provide the scale and Quality of Services (QoS) the IoT solution demands.

CHALLENGES

The pervasive growth of IoT requires a ubiquitous public network that is easy to use, able to transmit signal deeply into almost all locations, and has truly low-cost/low-energy device capability of operating for several years on a small battery. This is everything that the current LP_WAN technologies claim to provide however, the primary challenge in implementation comes from the fact that most LP_WAN technology options use unlicensed ISM (Industrial, Scientific, Medical) band. The QoS issue associated with public network level of deployment is raised due to unregulated network management protocols and restricted usage of the band. Secondly, there is a lack of an accurate ranging capability, which is critical for a mobile asset management application where time and location are the most fundamental information sets. Thirdly, scalability of millions of smart devices without collision in a public network continues to remain a practical challenge.

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AVAILABLE SOLUTIONS

The table below summarizes most known LP_WAN options, all of which uses a sub-G ISM band. (http://forum.thethingsnetwork.org/t/comparison-of-all-lpwan-technologies/256)

	LoRa	Nwave	OnRamp	Platanus	Sigfox	Telensa	Weightless -N	Weightless -P	Amber Wireless	M2M Spectrum
Range (km) (Caveat)	15 - 45 Flat: 15 - 22 suburban; 3-8 urban	10	4 (claims 25 x competition)	Several hundred meters	Rural: 50 Urban: 10	Up to 8	5+	2+ urban	Up to 20	
Brand (MHz)	Spread; varies by region	Sub-GHz	2.4 GHz	Sub-GHz	868;902	868 / 915 470 (China)	Sub-GHz	Sub-GHz	434, 868, 2.4 GHz	800/900
ISM?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Symmetric up/down?	Depends on mode. Can be.	No	No (4:1)	No	No	Yes	Uplink only	Not yet determined		
Data rate (Caveat)	0.3-50 kbps (adaptive)	100 bps	8 bps - 8 kbps	500 kbps	100 bps	Low	30 kbps - 100 kbps	Up to 100 kbps (adaptive)	Up to 500 kbps**	
Max nodes (Caveat)	Depends; millions/hup	Million/base	"10s of 1000s"	50k	Millions/hub	150k/ Server (moving to 500k)	No real claim - due to "it depends"	32767 NWs, 65535 hubs each, 16M edge device per NW	255 networks of 255 nodes	
OTA upgrades?	Yes	Yes	Yes	Yes	Doubtful	Yes	No	Yes		
Handoff?	No; no node/hub assoiciation	No; it's being considered	Yes	Yes	Doubtful	Yes	Yes	Yes		
Operational model	Public/Private (expect 80% public)	Public/Private	Public/Private	Public/Private	Public	Public	Public/Private	Public/Private		Public
Standard status (if any)	LoRa: No LoRAWAN: Yes	Weighless-N	No. Have taken to IEEE.	Weightless-P	No	No (possibly in the future)	Yes	In process; spec later this year		

The limitations of ISM bands and the country specific variations in selected geographies are shown below:

Frequency	Item	USA	Singapore	Europe	Korea
2.4GHz	Frequency Band (MHz)	2,400 – 2,483GHz (83MHz)	2,400 – 2,483GHz (83MHz)	2,400 – 2,483GHz (83MHz)	2400～2483.5MHz (83MHz)
	Output Power	<+30dBm (<1000mW)	<+20dBm (≤ 100 mW)	<+17.85dBm (≤ 60.95 mW)	<+10dBm (<10mW)
	Channel Allocation	NO RESTRICTION	NO RESTRICTION	NO RESTRICTION	NO RESTRICTION
900MHz	Frequency Band (MHz)	902 - 928 MHz (26MHz)	920 – 925MHz (5MHz)	N/A	915～923.5MHz (8MHz)
	Output Power	<+30dBm (<1000mW)	<+27dBm (≤ 500 mW)	N/A	<+10dBm (<10mW)
	Channel Allocation	NO RESTRICTION	NO RESTRICTION	N/A	<2% in 20seconds
800MHz	Frequency Band (MHz)	N/A	866 – 869MHz (3MHz)	868 – 868.5MHz (0.5MHz)	N/A
	Output Power	N/A	<+27dBm (≤ 500 mW)	<+14dBm (<25mW)	N/A
	Channel Allocation	N/A	NO RESTRICTION	0.01	N/A
400MHz	Frequency Band (MHz)	N/A	453.7 ~ 458.7MHz	433 - 434.8 MHz (1.8MHz)	N/A
	Output Power	N/A	<+30dBm (≤ 1000 mW)	<+10dBm (<10mW)	N/A
	Channel Allocation	N/A	NO COMMENT	<10%	N/A

SENAYA INNOVATION APPROACH:

When it comes to innovation, there are generally two text-book approaches - emerging or evolutionary.

The goal of emerging innovation is to identify a gap in the problem space and build a clean slate solution. On the other hand, the goal of evolutionary innovation is to leverage past and present knowledge and build incrementally on an existing time-tested solution. There are obvious trade-offs in both the approaches. The emerging innovation approach allows the innovator to build a system in an unconstrained way, breaking free from previous solutions. However, this approach is riskier from a practical point of view as it requires multiple cycles of learning that are expensive. This approach also requires "innovation selling" to the different stakeholders and are time consuming. The evolution approach obviously has lesser limitations on all these aspects.

Senaya's evolutionary approach to solving this problem proposes to use a basis of RADAR (Radio Detection and Ranging) technology called CSS (Chirp Spread Spectrum) technology, as a building block. This approach is similar to one of the current LP_WAN options - LoRa in combination with a future cellular option - LTE Cat.0 protocol.

CSS can be characterized as;

1. Superior ranging capability – Location accuracy
2. Superior robustness and high SINR - Long distance
3. Multi-paths fading resistance - Accurate ranging
4. Resistance against disturbances (NB and BB) - Reliability
5. Strong mobility (>100km/h – Mobile asset tracking
6. Anti-Jamming capability - Military and Security applications

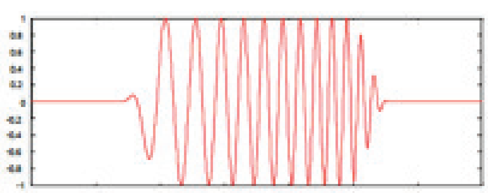
Chirp Signal Property

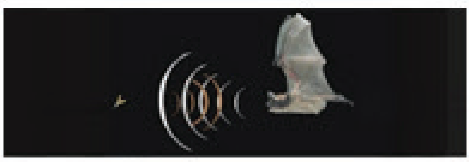
Wave Form: Rectangular Window

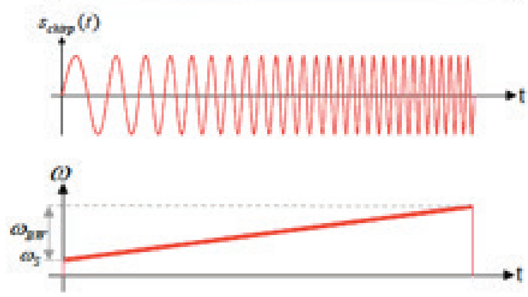
$$s_{chirp}(t) = \mathrm{Re}\left[\exp[j(\omega_s + \frac{\omega_{BW}}{2T_{chirp}}t)t + j\theta_0] \times [u(t) - u(t - T_{chirp})]\right]$$

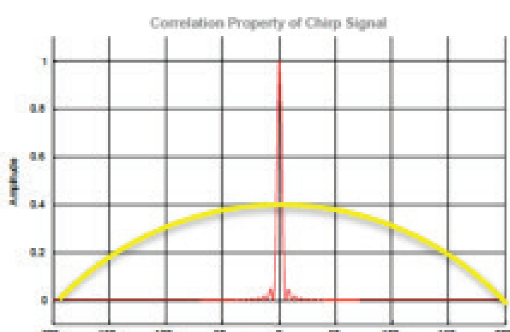
Wave Form: Raised Cosine Window

$$s_{chirp}(t) = \mathrm{Re}\left[\exp[j(\omega_s + \frac{\omega_{BW}}{2T_{chirp}}t)t + j\theta_0] \times p_{RC}(t)\right]$$









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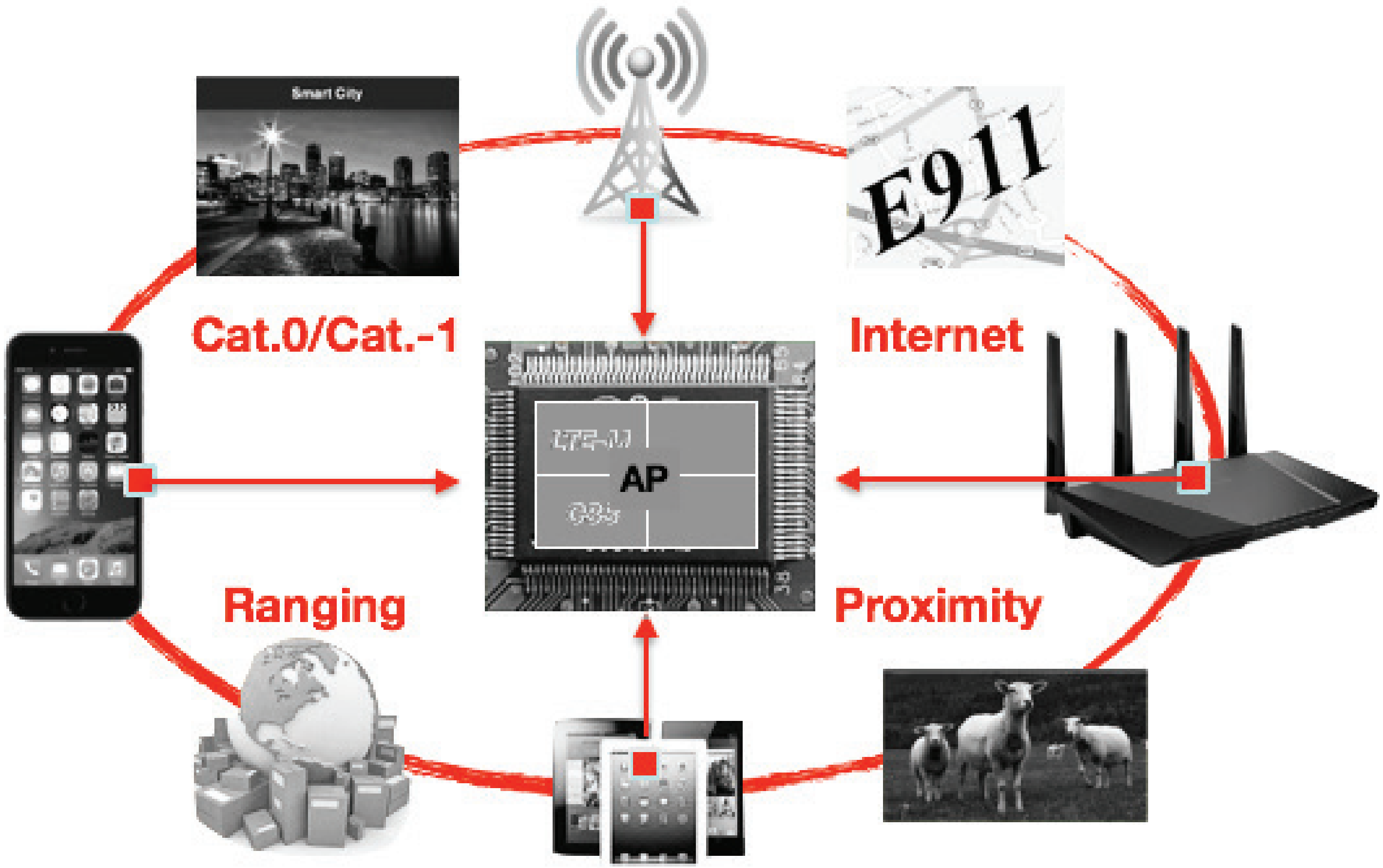
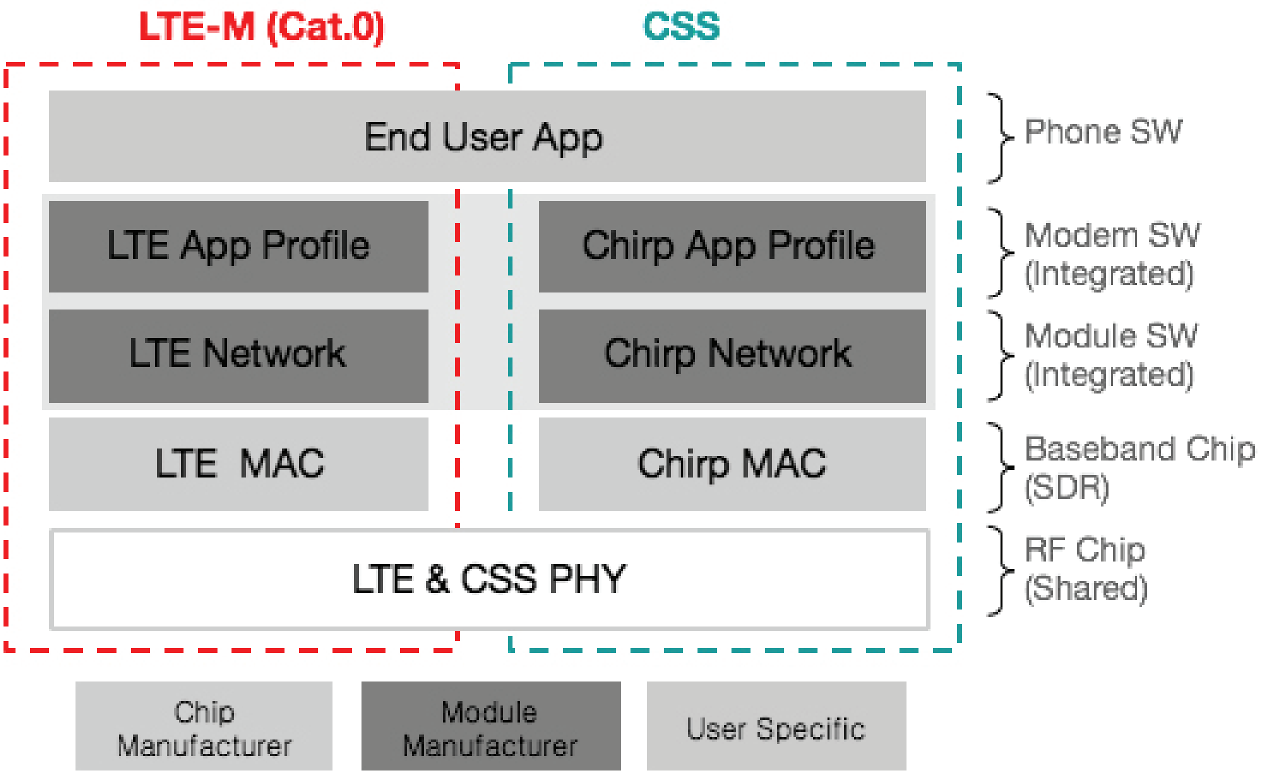
CSS performance does not depend on a baseband frequency or modulation method, as long as CSS modulation is intact. CSS technology is well understood through military applications and IEEE 802.15.4 standards. CSS can be integrated with 2.45GHz WiFi protocol and also with licensed sub-band packet, such as LTE Cat.0. The picture below describes the basic structure of baseband chipset integration options in a form of SoC chipset.

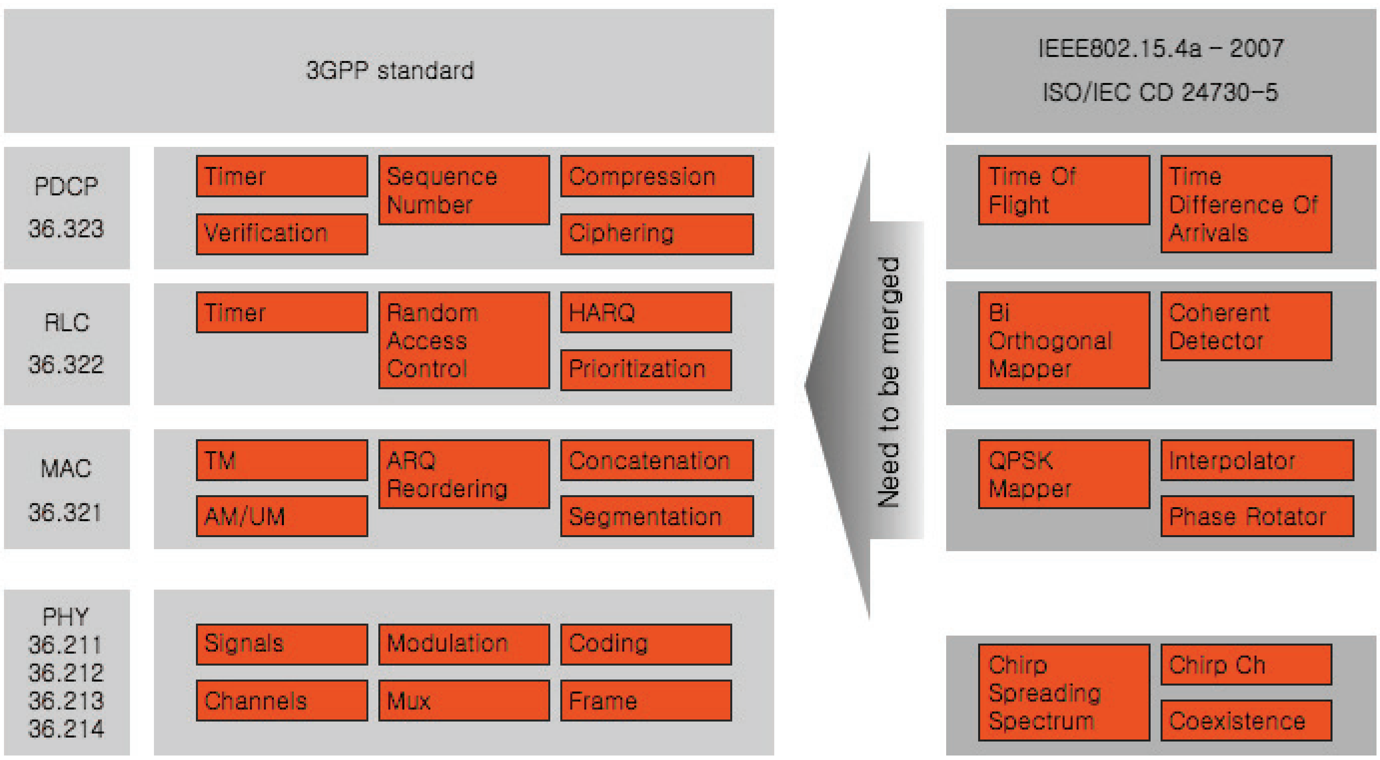


This architecture allows for Senaya LP_WAN interoperability with WiFi and cellular networks, which will facilitate the integration with existing infrastructure and make it easier to scale. The LTE and CSS layers are flexible and may either be shared or be separated depending on functionality and industry specific use cases.

Senaya LP_WAN proposes the following layer integration option as shown below.



For standardization, Senaya intends to work with 3GPP and IEEE standard bodies to maximize their experience and knowledge as depicted below, driving beyond LTE Cat.0 toward a proposed LTE Cat.-1



Finally, the overall architecture will have to be functioning organically without causing cross interference or collisions, and the proposed organization below vertically integrates LAN, WAN, and LP_WAN technologies through cross standardization efforts.

CONCLUSION

The proposed Senaya LP_WAN architecture can address the 3 key issues of QoS, ranging, and scaling while leveraging existing infrastructure. It is expected that this proposed solution will co-exist with other options such as conventional LP_WAN, C-IoT, and segmented LAN, PAN, and WAN. The most critical advantage of this approach is time to market (TTM). Leveraging proven technology components increases the probability of technology success significantly. Senaya has already conducted small scale pilots of this technology solution in logistics vertical and is of the view that the proposed option will prevail over other comparable solutions and will prove to be a game changer in the IoT industry.

Senaya
945 Concord Street
Framingham, MA 01701 USA

www.senaya.com