AN EDUCATIONAL GUIDE

HOW RPMA WORKS

RPMA

A WHITE PAPER BY INGENU

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Designed from the ground up for machine communications, Random Phase Multiple Access (RPMA) technology offers many advantages over traditional M2M/IoT connectivity solutions.

COVERAGE

At 300+ square miles per access point, RPMA offers unprecedented coverage ability over cellular technologies. While many factors are at play, efficient handling of signal transmission plays an important role. Transmission gains can come from augmenting power to a transmitting antenna or increasing receiver sensitivity and antenna gain. Transmission losses are incurred through obstructions, such as topography and made-made objects; cable loss, and other deleterious elements.

ANTENNA GAIN The antenna's efficiency of converting electrical power to radio signal

Signal power can be spent on various wireless communication wants and needs such as

- Using less infrastructure
- Deeper obstruction penetration
- Higher probability of coverage

Signal spent in one area reduces the amount that can be spent in other areas; it's a tradeoff. But if you have increase efficiency and make use of all possible signal gains, then you have more to spend on all areas.

Exponential Coverage Increases

One very important feature of transmission gains is that **unit differences in signal power result in exponential differences in coverage**. In simple monetary terms that would be like a store offering 1 candy bar for $1, 10 candy bars for $2, and 100 candy bars for $3. Though the prices differ by 1 unit each, what you can buy with the additional dollar differs exponentially. Table 1 shows that with only 25 more dBm over LTE, RPMA can cover 100x the area. RPMA's incredibly savvy use of all available transmission gains allows it to provide coverage very quickly over a very broad area, and to a great depth as well.

Where does RPMA get so much coverage?

RPMA gains its largest chunk of coverage from receiver sensitivity. Optimized receiver sensitivity provides a healthy amount of signal power while still maintaining an enormous amount of capacity. Transmission power is also maximized to the greatest extent that government legislation will allow. That is one of the reasons RPMA operates in the 2.4 GHz band of spectrum: it allows for greater transmission power. These factors combine to give a very rich signal strength and industry leading coverage per access point.

Table 1. Link budget and associated coverage comparison across wireless technologies.

Technology	RPMA				Cellular				Ultranarrowband			
Regulatory	FCC 2.4 GHz		Europe 2.4 GHz		CDMA		LTE		FCC 900 MHz		Europe 868 MHz	
Uplink/Downlink	UL	DL	UL	DL	PCS	Cell	PCS	Cell	UL	DL	UL	DL
TX Power	21	30	21	21	23	23	23	23	20	30	14	21
RX Sens.	142	133	142	133	121	121	118	118	134	129	142	137
Antenna Gain	17	17	9	9	14	14	14	14	9	9	9	9
Freq.Offset	0	0	0	0	0	9	0	9	9	9	9	9
Ant. Diversity	0	0	0	0	0	0	0	0	-8	-8	-8	-8
Noise Floor	0	5	0	5	0	0	0	0	-15	5	-5	5
TOTAL	180	185	172	168	158	167	155	164	149	174	161	173
Link Budget (Relative to RPMA)	180		168		158/167		155/164		149		161	
Coverage (sq. mi.)	300		33		5	27	3	16	1		9	

CAPACITY

Capacity is the ability of a single access point to support transmission of messages to and from some number of endpoints. Capacity is best measured in terms of total application throughput, or in other words, how much data can be successfully sent over a given interval. For wireless communication this is measured in bits per second per MHz (bps/MHz). RPMA can offer throughput of 19,000 bps/MHz. For reference, according to Ingenu engineering simulations this is over 54x the throughput of the next closest LPWA provider. This kind of capacity difference has very real world implications. Each RPMA access point can serve hundreds of thousands of endpoints with various data usage rates.

Capacity Scaling

RPMA was designed from day one to scale in a truly unlimited way. Perhaps one of the single most important factors when deciding which network to use is the ability for that network to scale as more endpoints are added. The 2G spectrum sunset has disturbed business operations and increased capital costs for many companies already, so technology sunsets should be avoided. In short, RPMA's smart modules use transmit power control so that as more access points and endpoints are added, they can adjust accordingly. RPMA is ready to scale to tens of billions of devices right now.

SPECTRUM CHOICE

RPMA utilizes the 2.4 GHz unlicensed and universal band, which offers 80MHz of bandwidth. This is not unlike having a highway with 80 lanes each 1 MHz wide. RPMA technology is efficient enough that its signal only requires 1 MHz channel width to support an entire network. As an example, San Diego Gas & Electric's entire 4100 square mile private RPMA network is run entirely on a single 1 MHz buffer at the far left frequency of 2402 MHz. But it needn't stop at 1 channel. With 1 MHz buffer on each side of a channel and 80 MHz of bandwidth available, you have 40 channels to choose from. This kind of bandwidth gives RPMA an enormous amount of flexibility for locating frequency with less traffic.

This enormous amount of bandwidth also gives RPMA serious power. With multichannel access points, the technology could theoretically support up to 40 channels simultaneously. A more plausible 8-channel setup would provide the power to support eight times the number of channels as a simple one-channel setup.

With delivery being essential, not best effort, RPMA goes to great lengths to guarantee delivery of each message sent over the network. The most basic layer is channel coding using the Viterbi algorithm, which allows for a drop of some portion of the signal while still guaranteeing the full message will be received. Specially crafted and state-of-the-art algorithms further guarantee message arrival even up to 50% Packet Error Rate (PER). Even if half the packets comprising the message drop out we can decode the entire message.

One of the great virtues of the 2.4 GHz band is that it is available worldwide. This is especially important as many partners have presence in more than just one country, or even one continent. Not only is it available worldwide but it is free worldwide. This allows Ingenu to pass cost savings on to its partners rather than pass the buck like cellular companies who have to bid for and lease their spectrum.

Transmit Power Control

The ability to adjust the "volume" of endpoints so that they do not always transmit at the same power. They can be reduced as more access points are added so that only the nearby access points can hear, and the farther away access points cannot.

Additionally, the 2.4 GHz band lends itself to favorable legal implications. Through legislation governments control some aspects of signal transmission such as the transmit powers and antenna gain. Transmit powers and antenna gain are better in 2.4 GHz than 900 MHz in Europe (868 MHz band). In the US, additional sectorization can be used to exceed 36 dBm EIRP (44 dBm can be achieved) to further improve network coverage and capacity.

In the US there are no regulations that limit the amount of processing gain for technologies like RPMA that use Direct-Sequence Spread Spectrum. However, narrowband, the other scheme for transmitting signals, requires longer transmission time to complete than is allowable under US law and so has great hurdles to be implemented nationwide. The 2.4 GHz band also has no duty cycle limitations in the US or Europe so that throughput and capacity are uninhibited by legislation.

HOW RPMA SENDS MESSAGES

Access points and endpoints are carefully synchronized so that endpoints send signal that fit inside of predefined frames of certain size. For each frame, there are thousands of potential signals that could have been sent. Endpoints send their signals with a random delay that is small enough to not exceed the frame size. The access point de-spreads, de-interleaves, Viterbi decodes, and then checks the signal via a Cyclic Redundancy Check (CRC). The difference of this scheme to a more conventional scheme is that more often than not, the CRC will indicate failure. In a conventional scheme, that usually means that the attempted transmission was received in error. In our system, it typically means that there was no attempted transmission at that particular offset and it's time to give the next one a try.

In addition to choosing signal delay, the endpoints unilaterally calculate the optimal (minimum) spreading factor to transmit at based on measurement of the downlink signal strength. The Access Point doesn't need to know beforehand which spreading factor the node will select because the Access Point brute-forces its way through all spreading factors at all possible delay times.

While receiving signal, RPMA endpoints are constantly aware of channel conditions and local interference levels. This information is continuously signaled back to Access Point during any downlink transaction. In this way, the endpoint receives at maximum supported data rate. Downlink capacity is increased by a factor of ~30 relative to always transmitting at worse case spreading factor. These techniques combined in this unique way allows RPMA

to support simultaneous demodulation of up to 1200 fully overlapping signals per sector that are all in the same frequency.

ENTERPRISE GRADE SECURITY

> One of the great virtues of the 2.4 GHz band is that it is available worldwide

Utilities, oil and gas companies, and others have trusted RPMA's enterprise grade security for years — security is built into the system from the ground up. With 256-bit encryption as well as two-way authentication, not only is the message garbled, it is guaranteed via a 16-byte hash. What this kind of hash means is that there is only a 1 in 2^{256} chance of someone randomly guessing the signature. To make the point further, 2^{256} seconds would be more than have ever been in the universe, and by a long shot. In comparison, other M2M/IoT connectivity solutions frequently use a 2-byte hash. This provides only a 1 in 64,000 chance of randomly guessing. With modern computing power, it would be a simple matter of brute force computing to obtain the signature.

Want more information?

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