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0G as Universal Utility: Universal Complement to Cellular and Short Range Communication Services, such as 5G, NB-IoT, LTE and WiFi, BLE, NFC

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Abstract

Despite the abundance of technical literature, academia, marketing and heavy advertising, promoting different communication methods, protocols and uses in IoT, there is little insight provided into the complex dynamics from a business, radio-engineering, practical technical perspective driving performance of both 0G and 5G[1] IoT Services, such as NB-IoT and Sigfox in the so-called LPWA space[2].

It is the authors proposition to consider the practical insights into each of these technologies in real-life decision making by clients today and use these insights to propose a logical self-contained framework of analysis, further research and conclusions.

In addition to multiple standard side-by-side comparisons focusing on bitrates, message size, propagation, battery consumption et al, the authors propose that the role of each 0G and 5G has to be considered in the context of (1) overall spectrum usage, (2) operator-type economic considerations such as market size/margins, opportunity costs and client retention (Operator View), (3) true full cost of ownership (Client View) over a mid-term forecast horizon, as well as (4) environmental footprint of / facilitated with it, and (5) cyber security, of the technologies considered here. These 5 aspects are dealt with in two separate working papers, this Number 6 and the following Number 7, given the variety and width of subject matters to be covered.

It is the authors **First Conclusion** that both NB-IoT and 0G are (1) largely addressing different markets/use cases, (2) mostly complement each other, and/or (3) in a few cases compete with each other and other technologies such as LoRa, Wifi, BLE or even Amazon Sidewalk.

The **Second Conclusion** the authors submit for consideration that 0G due to its specific physical properties is a ***Universal Sustainable Complement*** to all (cellular, near-field) communication strategies.
(1) $0G = \prod(Universal, Sustain, Complement)$

It is *Universal* in that it fulfills various components of universality: geography, openness, sustainability, affordability, reliability.

It is *Complement* in the sense that it allows to: (1) reach out - as primary connectivity - to use cases

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[1] 5G shall include NB-IoT as dedicated cellular technology (mMTC) for purposes of this paper

[2] Other protocols are not further discussed here, as less relevant in the context of *Universality* analysed herein

which are not otherwise possible/feasible,
(2) create additional redundancy layer to high-bandwidth (xMBB) and ultra-reliable MTC (uMTC), as well as other short range methods and protocols (BLE, NFC, wifi,...), (3) offload traffic (temporarily or permanent) in a flexibly managed virtual network slicing environment without compromising MNOs user experience or service levels for various customer groups.

It is *Sustainable* as it enforces data & energy efficiency, smallest devices and enables efficiencies in all sectors. In particular, it fosters dietary usage of data from the beginning, providing a genuine filter for what is truly necessary and what is not.

As **Third Conclusion**, the authors postulate that 0G has the unique physical qualities[3] to become an additional robust layer for all communications going forward, while at the same exercising discipline on data generation and usage as well as allowing massive further growth and effectiveness within spectrum usage due its offloading capability.

Looking ahead, such proposition would make 0G a **Universal Utility** which could by law and by desire to be available to all potential users on a reasonable and non-discriminatory basis.

While this paper is introducing the general concept of universality, redundancy and market bifurcation, the next paper is discussing the client side and operator dynamics in more detail as well as quantifying some aspects of cyber security considerations.

Keywords

0G, 5G, NB-IoT, Cellular, Short Range, Cyber Security,

Labelling 0G

0G is not an approved or even yet widely accepted technical term. Rather it is used as a practical, easily communicated short hand to express LPWAs different from and opposition to 5/4/3/2/1G / NB-IoT cellular approaches.

It is in opposition to, as it is non-cellular (*sic* “0”)[4], limited in data volume, with lowest energy consumption and other differing radio characteristics of relevance[5]. As such it is a label to highlight the fundamental difference to the pre-vailing 5G marketing campaigns for digitisation.

Retrospectively, 0G is sometimes used to refer to the antecedents of 1G [6] (so-called pre-cellular systems) which originated between 1946 and 1950s. Equally, in Germany there were other mobile phone services offered from trains via the so-called Zugpostfunk[7], which some claim should be called 0G, as it is the antecedent to the antecedent of 1G and its followers. This interpretation may well also be valid, but re-interprets past systems through todays lenses.

We propose the use of 0G as short hand for non-cellular, focusing on existing and deployed radio protocols today.

Current Research Situation

Any person without radio-engineering background will be confused. Confused about the different parameters, tests, characteristics and marketing which is being put forward for 5G, NB-IoT, LoRa and Sigfox. While there is significant academic research available (list available upon request), none of these addresses the issue of applying these solutions in practise,

[3] Combination of wave length, propagation characteristics, UNB usage, resulting device sizes, unlicensed band usage, …

[4] One could argue the communication has no “gravitational” center as it is non-cellular, but that would go beyond the purpose here.

[5]

[6] See https://en.wikipedia.org/wiki/Mobile_radio_telephone

[7] https://de.wikipedia.org/wiki/Zugpostfunk

and in a proper "blind" test. Rather, then focusing on theoretical or at best laboratory type conditions, it is important to create a framework of evaluation in real life.

The authors encourage the interested community to do this and publish results.

Even a matter as straight forward as energy consumption of a device becomes rather complex, when making the transition from theory to practical application.

For example, the function describing the life of a device with one battery charge L(batt) (if any) is driven by various factors. There is the availability of energy harvesting elements (eh), the available metric volume and dimensions for energy storage (dim), the energy density /cbm (den), the necessary sensory activity and its consumption (s), the laboratory test configuration transmission consumption (l), the variability of transmission energy required due to the specific radio and network environment[8] (vre), the message size, speed and overheads to be transmitted (m) and its frequency (f) and the natural discharge of any electric capacity in different environments (dis), to name but a few.

$$L\ (batt) = f\ (-\frac{(den\ x\ dim)}{\sum_{x=\frac{L}{f}} \prod (m, l, vre(l)_x)}; -dis; +eh)$$

The availability of energy harvesting elements, as well as larger battery obviously extends lifetime, while natural discharges reduce and higher consumption or higher frequency of transmission reduce it.

Thus, any table highlighting the useful life of a device in order to make comparison between 0G, 5G etc is by default misleading if not providing a whole range of detailed assumptions and conditions making the apparently "easy" comparison wrong and misleading[9].

The issue is that in cellular mode *vre* is a variable which differs with every single transmission and its environment (if not stationary all life).

Finally, cyber security instalments will become a significant user of bandwidth and message load in particular for 5G and NB-IoT as well as other HDV technologies as the attack surface is increasing significantly, impacting both (m) and (f) materially. And this only refers to battery life impacts.

	LTE[6]	LTE-M[4]	NB-IoT[5]	LoRa	Sigfox
Spectrum	Licensed	Licensed	Licensed	Unlicensed	Unlicensed
Bandwidth	20 MHz	1.4 MHz	180 kHz	125 – 500 kHz	200 kHz
Bidirectional Data Transfer	Full duplex	Half duplex & full duplex	Half duplex	Half duplex	Half duplex
Peak Data Rate	10 Mbps (DL) 5 Mbps (UL)	1 Mbps (DL)[2] 1 Mbps (UL)[2]	250 Kbps (DL)[3] 230 Kbps (UL)[3]	50 Kbps (DL) 50 Kbps (UL)	0.6 Kbps (DL) 0.1 Kbps (UL)
Typical Downlink Daily Throughput	Limited only by battery power, radio signaling condition and commercial terms (e.g. monthly data volume, amount of messages/size per period)			~ 200 B	~ 24 B
Typical Uplink Daily Throughput				~ 200 kB	~ 1.64 kB
Max. Coupling Loss (vs. GSM)	144 dB (0 dB)	156 dB (+12 dB)	164 dB (+ 20 dB)	157 dB (+13 dB)	153 dB (+ 9 dB)
Expected Module Cost	> $ 10	< $ 10	< $ 5	< $ 7	< $ 3
Expected Max. Battery Lifetime[1]	3 – 5 years	5 – 10 years	10+ years	10+ years	10+ years

Table 1: Overview of IoT transmission technologies

[1]Assuming typical traffic pattern and battery size.
[2]These values relate to full duplex mode. Currently observed mean rates, based on half duplex transmissions, are around 350 kbps (DL/UL).
[3]These values relate to overall cell capacity. Currently observed mean rates, based on single tone transmission, are around 20 kbps (DL/UL).
[4]Relates to 3GPP Cat-M1 specification Rel. 13.
[5]Relates to 3GPP Cat-NB1 specification Rel. 13.
[6]Values relate to LTE-Cat 1 category.

[8] Covering repeats, waiting loops, adjusted signaling power, etc, etc.

[9] In table published by Deutsche Telekom all three radio technologies exhibit battery life of 10+ years, "assuming typical traffic pattern and battery size". While in 0G achievable with a CR 2032 battery it is difficult to conceive in reality with NB-IoT for example.

Only if all these aspects are properly considered a client can make an educated conclusion. The driving force are mostly the external, practical, statistical and physical constraints under which devices are being deployed. This can be the space available, the sheer number of devices, the predictability of target locations, as well as the other environmental and radio aspects. Also, the cost of *visiting a device maybe as high as buying it in the first place*.

While clients have to face these issues, this is mostly not a formalised process, and there is little if no literature with practical relevance available. Also, client decision making cannot become a theoretical dissertation about all these factors above. So, beware of simple hooks. Look at the practical results of field tests.

However, we can conclude that some testing and choices must have taken place, as companies such as La Parisienne, DHL, Amadeus, Eutelsat, Tokyo Gas, Airbus, Securitas, etc.. have chosen 0G solutions already. Mostly, the use cases here are complex mobile ones.

We may thus conclude that for mobile low data volume messaging 0G has convincing characteristics, as evidenced by an increasing list of these global customers.

Complement or Competition?

Without further detailed evidence, it appears that there is a *bifurcation* of the market of use cases taking place into (1) larger data volume markets for billions of devices (smart phones, industrial IIoT,…), whether they called IoT or not, and (2) those which have very low volume requirements, but also for – ultimately – billions of devices.

These two segments ***do not*** align with common terminology such as IoT, IIoT, Industry 4.0, LPWA, cellular/non-cellular, 5G or NB-IoT, as these are technology driven definitions.[10]

In a certain way this also reflects the underlying nature of the IoT movement, as it is driven by engineering developments looking for the use case market to fit their technology, rather than the other way around.

As a result, the **bifurcation of the market for use cases** is the relevant driver to define markets, not the existence of different technologies.

As an example, NB-IoT in particular is based on scaling down a given technical cellular architecture to meet all possible needs, including lower data volume. This can be successful only to some extent. Of course, easy wins, such as no news/no message, have been implemented. The core of the assignment of spectrum space and coordination with the cell still remains, and reflects itself in the high variability of energy consumption. And of course, with the benefit of higher data transmission capabilities for both payload and protocol, even Firmware Update over the Air (FOTA). However, does it make sense to the use case? Is it shooting with cannons on sparrows?

As prices for connectivity and devices in the Low Data Volume Market (LDV) go down to a few dollars per year and device, the operating cost of maintaining all support in a complex cellular environment (marketing, device management, e-sim handling & provisioning, billing, cyber protection, network slicing, etc) becomes highly relevant. Put in another way: is the cost of running a 5G / NB-IoT service worth the revenues generated within the LDV markets.

In comparison with the revenues to be generated by High(er) Data Volume (HDV) markets, these operating costs are likely to be unacceptable and not easily absorbable.

[10] See in more detail the working paper No 7 in this series.

High(er) Data Volume (HDV) markets however, mobile or stationary, are applications which can be readily served via 5G and NB-IoT or even other LPWA methods.

Also, we are ignoring happily from an operators perspective the sunk cost of spectrum usage and the initial upfront investment. It is worthwhile noting that these costs are sunk, which is good for manufacturers, but bad for investors in MNOs. Equally, the authors have not been able to find proper assessment of opportunity cost originating when dedicating guard or inband usage to LDV when HDV is available as well.

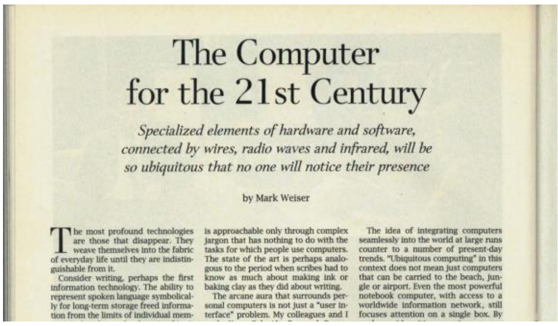
What appears to be happening in the LDV market, is that neither the client perspective is fully worked out (due to lack of transparency of available comparisons and misleading advertising), **nor** the operator perspective, as manufacturers are driving the agenda to foster purchase of equipment by MNOs without a clear path to revenues for the high-spec tech being sold in LDV markets.

Universality of 0G

In order to be a universal solution, a technology has to fulfil – depending on the observer – various criteria, including geographical, technical, design, economic, political and of course practical criteria.

0G as proposed by Sigfox is Universal in the sense that it is ubiquitous[11], inert, not fragmented, highly affordable and agnostic to which type of cellular communication strategy is being deployed in a particular geography or vertical setting, ie no bandwidth competition or SNR impact[12]. It allows various design solutions to fit use cases in various environments.

It is also Universal in a sense that its spectrum usage is in the unlicensed bands only, while fully complying with duty cycle restrictions, delivering industry/standard SLAs across many countries, while the radio protocol is open to the public and while there is no closed eco-system linked to a particular manufacturer either de facto[13] or by license[14]. 0G is a by all means an open standard[15].


The Computer for the 21st Century

Specialized elements of hardware and software, connected by wires, radio waves and infrared, will be so ubiquitous that no one will notice their presence

by Mark Weiser

The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it.

Consider writing, perhaps the first information technology. The ability to represent spoken language symbolically for long-term storage freed information from the limits of individual mem-

is approachable only through complex jargon that has nothing to do with the tasks for which people use computers. The state of the art is perhaps analogous to the period when scribes had to know as much about making ink or baking clay as they did about writing.

The arcane aura that surrounds personal computers is not just a "user interface" problem. My colleagues and I

The idea of integrating computers seamlessly into the world at large runs counter to a number of present-day trends. "Ubiquitous computing" in this context does not mean just computers that can be carried to the beach, jungle or airport. Even the most powerful notebook computer, with access to a worldwide information network, still focuses attention on a single box. By

Figure 1 – M Weiser in:
Scientific American September 1991

Also, it is available without the user having to do anything in terms of set up, and it is not that there is a cooperation between multiple different operators necessary (roaming), or to create device-to-device communication protocols to get information (mesh), the latter with all practical implications for GDPR, cyber-security and alike.

Finally, it is well placed as a redundant technology, in a sense that it is independent from others, and thus provides Genuine Redundancy in a engineering sense. The fact that Sigfox is one telco operator as opposed to a multitude of different operators in each country has both advantages and disadvantages depending on the clients needs and expectations. So far, the fact

[11] It is a global network, available both indoors and outdoors, soon complemented by satellite, fulfilling criteria of „ubicomp“, the vision defined by legendary Mark Weiser, in: "The Computer for the 21st Century" - Scientific American Special Issue on Communications, Computers, and Networks, September, 1991

[12] As may be the case with NB-IoT in guard band deployment, ie no complete isolation despite being deployed in guard band

[13] Considering the well publicised case of Huawei

[14] Considering Semtech role in the LoRa ecosystem

[15] https://en.wikipedia.org/wiki/Open_standard, except for payment is necessary to use the infrastructure enabling Sigfox, still ITU-T compliant

that there is a global provider gives ability to discuss global or larger regional deployments easily.

It is the authors conclusion, that 0G as proposed by Sigfox addresses various of these aspects. It is one system which is accessible – ultimately – everywhere on the globe (including satellite)[16].

Also, given that it is a European technology, there is a strong argument that all issues of political interference or GDPR compliance are most likely neutrally handled.

0G as Redundancy Layer

Baron Munchausen (see picture below) by legend was able to pull himself out of a mire by his own hair. This is also referred to as the ***Munchausen Trilemma*** [17] or the "Bootstrap Paradox" [18].

As the complexity of 5G increases, it being principally a software architecture, not radio architecture[19], also the attack surface for hacker attacks and other intervention of an unauthorised nature increases[20].

As a result, any proposition that cyber-security can be ensured in all critical processes within the architecture itself, is logically impossible (Munchhausen).

Adding another radio-physical (!) layer of security, therefore adds additional redundancy without cross-correlations, **enhancing the stability of the new combined system.**

Of course, 0G has also exploits and vulnerabilities, but these are of a different nature (see various publications in this regard, available upon request).

However, its inherent inertia, defined as very slow transmission of very little data, practically immune against malware of any kind, as the SLOC (lines of codes) gate is too small to allow attacks. Referring to Munchausen, it is as if 0G is the mire itself: high latency, slow, sticky.

Conclusion

0G as an additional radio-physical layer separate from cellular and other short range radio transmission methods, fulfils certain generally valid concepts, such as Universality, Complementarity and Ubiquity. This is paired with a strong contribution to sustainability and an open eco-system. The Authors propose thus, that 0G as proposed by Sigfox has all features of a ***universal utility.***

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[16] See announcement with Eutelsat

[17] Münchhausen trilemma is a thought experiment used to demonstrate the impossibility of proving any truth, even in the fields of logic and mathematics. If it is asked how any given proposition is known to be true, proof may be provided.

[18] Bootstrap paradox – Sequence of events in which an event is among the causes of another event, which in turn is among the causes of the first-mentioned event

[19] *See* Report: EU coordinated risk assessment of the cybersecurity of 5G networks, https://ec.europa.eu/commission/presscorner/detail/en/IP_19_6049, for detailed assessment.

[20] See quantification in paper No 7 of this series