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5G NB-IoT: Efficient network call admission control in cellular networks

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Summary

The International Telecommunications Union defines in its IMT-2020 recommendations three types of use of 5G services: mMTC (massive Machine-type Communications), eMBB (enhanced Mobile Broadband), and uRLLC (ultra-Reliable Low Latency Communications). The mMTC service allows a considerable number of machines and devices to communicate while guaranteeing a good quality of service. The eMBB service allows very high data throughput, even at the cell border. The uRLLC service is used for ultra-reliable communication for critical needs requiring very low latency. These services are provided separately in a given cell. However, the number of connected objects is starting to increase rapidly as well as the bit rates and energy consumption. The 5G network must make it possible to provide access to a vast number of users of its different service categories. Call admission control (CAC) techniques focus more on availability in terms of bit rate and coverage. In this article, we suggest an algorithm for modeling CAC in an area served by the three categories of services in a 5G access network, mainly based on minimum energy consumption. This technique will allow connected objects that consume low energy to connect to the network with an adequate quality of service and enable the development of the Internet of Things.

KEYWORDS

5G, applied computational intelligence, call admission control, eMBB, IoT, MTC, uRLLC, ultra-dense network

1 | INTRODUCTION

Since the beginning of the 1980s, several generations have succeeded one another. The transition from 1G to 2G was mainly the switch from analog to digital. The transition from 2G to 3G was the transition from low bit-rate voice and data services to high bit-rate multimedia services. 3G cellular technology is designed to support wide-band services, namely high-speed Internet access and video and high-quality image transmission. The transition from 3G to 4G technology has enabled a significant increase in throughput based on a considerable improvement of the architecture and a significant improvement in voice over IP (VoIP).[1]

5G technology primarily aims to ensure more reduction of latency, increase of indoor coverage by including small cells as well as outdoor. The 5G also seeks to increase the coverage, cost reduction, increase spectral efficiency, bit rates, guaranteeing a good quality of service (QoS), and energy-saving.

As defined in the next generation mobile networks (NGMN),[1] energy is defined as the number of bits that can be transmitted per Joule of energy. The power is computed over the whole network, potentially including legacy cellular technologies, radio access, and core networks and data centers.

In this article, we present the evolution of access networks in different generations of mobile networks from 2G to 5G and then various methods used in CAC. After that, we present a CAC method's suggestion based on optimal energy consumption in an ultra-dense network, as usually used in 5G.

As defined in the NGMN white paper for 5G,[1] energy is defined as the number of bits that can be transmitted per Joule of power, where the energy is computed over the whole network, including potentially legacy cellular technologies, radio access, and core networks and data centers.

Most research on call admission control (CAC) in mobile networks focuses more on the densification of networks, for example, by suggesting the multiplication of antennas, in particular, MIMO and also by focusing on good management of the frequency spectrum and the use of beamforming and even on coverage and bit rates.

In this article, we instead focused on the access of objects that consume a tiny amount of energy; in this case, the objects connected to the small cells attached to the macrocell. Thus, they allow responding to massive connections of these objects and, therefore, rapidly developing the Internet of Things. Other users who consume more energy will be connected by different base stations, which are also attached to the macrocell.

The article is organized as follows: in the next section, we give details about call admission control (CAC) in mobile networks. The energy consumption of mobile networks is described in Section 3. The proposed energy efficiency proposal for IoT call admission control in 5G Network is given in Section 4. 5G propagation models are presented in Section 5. Some applications for IoT and Tactile Internet in 5G are provided in Section 6. Finally, conclusions are drawn in Section 7.

2 | CALL ADMISSION CONTROL (CAC) IN MOBILE NETWORKS

2.1 | CAC evolution in mobile networks

Call admission control (CAC) aims to decide whether a new call request can be accepted without causing an unacceptable loss of quality of service to the users. Any interruption of communication in progress (dropping call) is more troublesome than the blocking call from the users.[2] In general, there are two categories of CAC systems in mobile cellular networks, namely deterministic CAC and stochastic CAC.[3]

In 2G mobile network uses either FDMA (frequency division multiple access) or TDMA (time division multiple access), frequencies and time slots are managed. Hence for CAC, the GSM network allocates both frequency and time slots to each new user. However, high-speed circuit switched data (HSCSD), general packet radio service (GPRS), and enhanced data rates for global evolution (EDGE) allocate more than one-time slot per user by using, for instance, statistic multiplexing.[4]

In 3G network (WCDMA), power control is used for adjusting the transmit power of the UE and BS (NodeB) to the minimum levels within the required QoS and for creating minimal interference to the other users. Furthermore, power control is needed to increase the system's capacity, compensate fading on the radio channel, eliminate or reduce the near-far effect, and reduce battery consumption. The admission decision must respect mainly at least two conditions. First, a mobile whose admission would lead to a network where the power is impossible to control must be refused. Second, a mobile whose admission would lead to a network that can always be controlled in power should not be refused.

Thanks to 4G LTE technology, user can demand and run simultaneously different services, such as web browsing, real-time gaming, and streaming video.[5-7] Each service has different quality requirements. For this technology, the main criteria are that the total number of physical resource block (PRB) per transmit time interval (TTI) required by the new user and the active users in the evolved NodeB (eNodeB) must not exceed the number of PRBs in the system.

Several initiatives have been taken to reduce energy consumption in the 4G network as much as possible. For 4G networks, many kinds of research have been carried out to develop techniques such as those relating to carrier aggregation. Others relating to the self-organizing network (SON) to optimize coverage according to user needs (power reduction, standby of cells coordinated by the network), reduction of the overall consumption of e-NodeB, reduction of the consumption of equipment by optimizing, for instance, their design, reduction of the use of air conditioners and also the sharing of infrastructure between operators while respecting international and national regulatory constraints.

For 5G technology, the International Telecommunications Union (ITU) identifies three main use cases:[8]

- mMTC (massive Machine-Type Communications): communications between numerous devices, with multiple quality of service needs. This category aims to respond to the density of connected objects, which is exponentially increasing. It connects objects such as heart monitors and portable objects. It also allows connecting cars and infrastructure, alongside with connecting devices to smart homes and smart cities.
- eMBB (enhanced Mobile Broadband): ultra-high-speed connection both outdoors and indoors with a suitable quality of service, even at the border of the cell. Features related to virtual and augmented realities and those related to video calls will benefit from these technological advances;

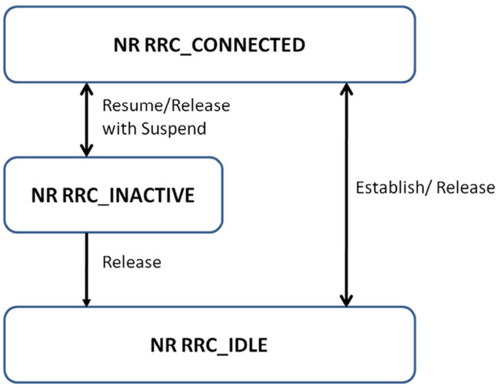

FIGURE 1 Different RRC states in 5G NR

- uRLLC (Ultra-Reliable and Low Latency Communications): ultra-reliable communications for critical needs with very low latency, for increased responsiveness. Many uses will be made possible thanks to the reliability and responsiveness of the 5G network, such as autonomous cars, which must quickly re-act and, in real time, to encounter situations. Besides, medicine (e-health) and industry (professional applications of connected devices) will also be impacted.

2.2 | RRC state in 5G

Radio resource control (RRC) is responsible for mainly the management of signaling messages between the base station (gNB) and user equipment (UE). A new state "RRC Inactive" is added in 5G NR compared with LTE as defined in 3GPP 38.331 standard (Figure 1). RRC states are a solution for system access, energy-saving, and mobility optimization. 5G technology must support eMBB, uRLLC, and mMTC services with the same cost and energy dissipation per day and zone.[4]

3 | POWER CONSUMED IN THE MACROCELL IN A UDN

Energy consumption of a mobile network is dominated by the base stations (BS), which currently consumes around 80% of the total power.[9] The power consumption of each base station depends on its type (i.e., macro, micro, pico, or femto). The main benefits with the implementation of CRAN (cloud/centralized radio access network) in 5G are improved energy efficiency and cost reduction. A basic unit regrouping all the "intelligence" and RRH (remote radio head), simple transmitting/receiving antenna, mainly transposing into frequencies.[10]

The main components of a base station are shown in Figure 2, where base station components are divided into two blocks. The first block is composed of a microwave link (backhaul). This block is typical for all sectors.

The second block is dedicated to each sector. It consists of the power amplifier (PA), which converts the power of the direct current (DC) into a radio frequency signal (RF), a transmitter (TX) and a digital signal processing (DSP), for converting the signal into a series of bits (or symbols).

As indicated in this article, we considered an ultra-dense network (called heterogeneous network [HetNet]) in which there are many macro-cells, and to each macrocell are attached many small cells called remote radio head (RRH) (as shown in Figure 3).

The consumed power, P_{BS}, by a base station BS (macro or small cell) is given by the following formula (1):

$$P_{BS} = N_{TX} N_{Sect} N_c (P_0 + P_{TX} + P_{fL} + P_{PA})(1 - G_{DTX}), \tag{1}$$

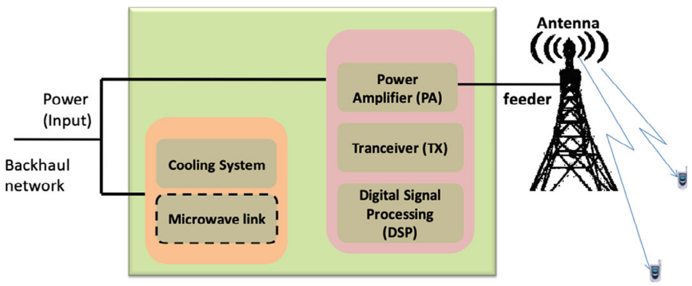

FIGURE 2 Macrocell base station components

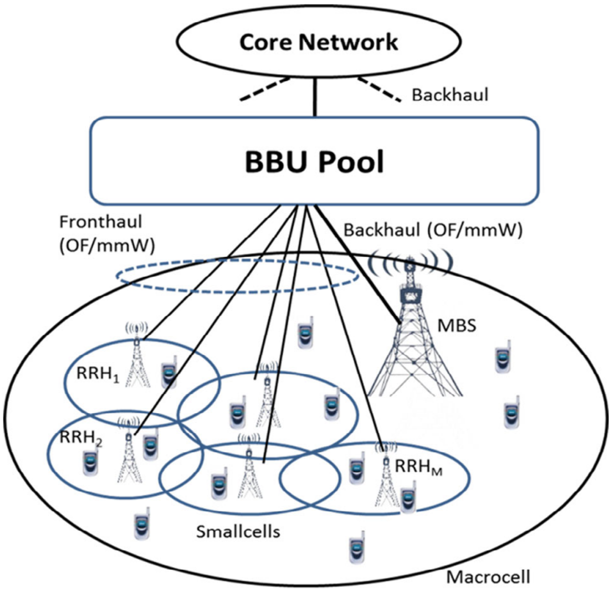

FIGURE 3 Macrocell in H-CRAN 5G environment

where

P_{BS}:	power consumption modeling of the base station (MRRH or RRHk)
N_{TX}:	number of transceivers
N_{Sect}:	number of the sectors
N_c:	number of the carriers
P_{TX}:	transmission power consumption
G_{DTX}	gain due to discontinuous transmission (DTX) mechanism

and P_{fL}, P_{PA} are power consumption depends on the transmitted power due to feeder losses and the power amplifiers, respectively.

The discontinuous transmission mode, DTX, is used to reduce the base station power consumption by switching into sleep mode during small periods in each frame.[4-11] We denote by:

$$\gamma_1 = P_0 + P_{TX} + P_{fL} + P_{PA} \quad \text{with } 0 \le P_{TX} < P_{max} \quad \text{for active mode,} \tag{2}$$

$$\gamma_2 = P_{SM} \quad \text{for sleep mode,} \tag{3}$$

$$\gamma_2 = \mu P_{SM} \quad \text{for deep-sleep mode,} \tag{4}$$

and

$$\lambda = N_{TX} N_{Sect} N_c (1 - G_{DTX}), \tag{5}$$

where

P_{max}:	the maximal transmission power consumed by a BS (MRRH or RRHk)
P_{SM}:	power consumed by a BS (MRRH or RRHk) in sleep mode
μ:	part of P_{SM}, with $0 < \mu < 1$

Hence, the total power consumed by each BS (MRRH or RRHk) is:

$$P_T^{BS} = \alpha_1 \lambda \gamma_1 + \alpha_2 \gamma_2 + \alpha_3 \gamma_3 \quad \text{with } \sum_{i+1}^{3} \alpha_{i=1}, \tag{6}$$

where P_T^{BS} denotes the total power consumed by a BS (MRRH or RRH$_k$) $\alpha_1, \alpha_2, \alpha_3$ are binary numbers that take the value 1, respectively if the BS is in active mode, or sleep mode or deep-sleep mode (advanced sleep mode), otherwise they take the value 0.

Hence, if we denote P_T^{MRRH}, the total power consumed by the MRRH in the macrocell, and $P_T^{RRH_k}$, the total power consumed by each RRH$_k$ in small cell, we can deduce the total power, P_T, consumed by the macrocell:

$$P_T = P_T^{MRRH} + \sum_{k=1}^{M-1} P_T^{RRH_k}. \tag{7}$$

4 | CALL ADMISSION CONTROL WITH LOWER ENERGY CONSUMPTION IN 5G

In this section, we study call admission control (CAC) at the level of an RRH belonging to a macrocell in an H-CRAN environment. We consider an RRH serving K user equipment UE. Each UE has a different service and a different bit rate with an acceptable QoS. In this section, we propose an algorithm for handling new demand while considering energy consumption constraints as a prime requirement for this new user. We denote, in the following, P_{max}^{RRH} the total maximal power in the cell and P_T^{RRH} the full power consumed by serving the K users.

If a new request for a $(k+1)$th user occurs, the cell resource management system calculates the possibility of admitting it in the cell according to the rate of the service D_{k+1} and the requested QoS. Therefore, the system must be able to deduce the additional power that must be consumed P_{K+1} , if the cell accepts to introduce this new user. If this additional power added to the total power does not exceed the total power of the RRH, then this new user is admitted. Otherwise, he is refused. For this, we are interested in the radio part between the RRH and the user equipment. It is necessary to estimate the minimum power that an RRH must bear to allow the guaranteed bit rate to users.

It should be noted here that the signal power characterizes the channel's quality to interference and noise ratio (SINR). The different powers involved are measured at the symbol level, at the output of the various interference reduction treatments of the receiver (in particular of the equalizer), and before the channel decoding. The bit rate that can be offered to each user equipment (UE) depends directly on the corresponding *SINR*.

4.1 | Case of mMTC and eMBB services

Considering these two use cases, we can assume that maximum bit rates (capacity) can be reached for a given *SINR* by Shannon's capacity formula, where B_k is the bandwidth of the transmission (in Hz). Hence, by using the Shannon's formula, for complex baseband additive white Gaussian noise (AWGN) channel, we calculate the maximum bit rate, C_k, required by a UE$_k$ $(0 < k < K+1)$ in the cell, as the following:

$$C_k = B_k \log_2(1 + SINR_{jk}), \tag{8}$$

where C_k is the bit rate required by UE$_i$, B_k is the bandwidth of a UE$_i$. $SINR_{ij}$ denotes the signal to interference plus noise ratio between transmitter j and receiver k. We consider here downlink transmission.

Formula (8) relates to the transmission of a single block of data. There are other more detailed formulas giving the channel capacity for specific transmission scenarios, notably multiple input multiple output (MIMO) where several blocks of data are transmitted on the same resources.

$SINR_{kj}$ can be obtained as:[12]

$$SINR_{kj} = \frac{\frac{P_{TX}}{PL_{kj}}}{\sum_{k \neq i} \frac{P_{TX}}{PL_{kj}} G_{kj} + B_k N_0}, \tag{9}$$

where

k:	each interfering link
PTX:	transmitted power
$PLkj$:	path loss between the receiver UE and the BS
G_{kj}	beamforming gain
B_i:	total bandwidth for UE$_i$
N_0:	noise power spectral density

we have

$$SINR_{kj} = \frac{\frac{P_{TX}}{PL_{kj}}}{I + B_k N_0},$$

where $I = \sum_{i \neq k} \frac{P_{TX}}{PL_{ij}} G_{ij}$ is the total interference caused by other UEs in the cell. Then,

$$\frac{C_k}{B_k} = \log_2(1 + SINR_{kj}),$$

$$1 + SINR_{kj} = 2^{\frac{C_k}{B_k}} \Rightarrow SINR_{kj} = 2^{\frac{C_k}{B_k}} - 1 = \frac{\frac{P_{TX}}{PL_{kj}}}{I + B_i N_0}.$$

Hence, we deduce the value of P_{TX} as the following:

$$P_{TX} = (2^{\frac{C_k}{B_k}} - 1)(I + B_k N_0) PL_{kj}. \tag{10}$$

The minimum transmission power $(P_{TX})_{min}$ is given by:[4]

$$(P_{TX})_{min} = (2^{\frac{(C_k)_{min}}{B_k}} - 1)(I + B_k N_0) PL_{kj}, \tag{11}$$

where PL_{kj} is path loss model. If a new user is accepted, the consumption power will be given by:

$$(P_T^{BS})_{new} = P_T^{BS} + (P_{TX})_{min}. \tag{12}$$

The formula (13) used generally to calculate the fading of signal is the following[13]

$$L(dB) = 32.45 + 20n \log_{10}\left(\frac{d}{d_0}\right) + 20n \log_{10}\left(\frac{f}{f_0}\right). \tag{13}$$

where

L:	Power loss in dB
n:	Pathloss exponent
d:	Distance between transmitter and receiver (km)
f:	Frequency used (MHz)

The flow chart of the simulation model is given in Figure 4.

Figure 5 shows the path loss per frequency and coverage distance. Remark in this formula that $f_0 = 1$ MHz and $d_0 = 1$ km, the reference values are arbitrary and chosen to be convenient to use values in MHz and km. The constant 32.45 changes if the reference frequency f_0 and the reference distance d_0 are chosen to be different. By using this formula (13), we can have some values of path loss per frequency (f) and per distance (d) as shown in Table 1

4.2 | Case of uRLLC service

URLLC applications guarantee 1 ms or less and reliability of $1 - P_e$ or less with $P_e = 10^{-5}$. In 5G, the uRLLC use case requires sending very short packets due to the low latency required. Therefore, the impact of a transmission error (τ_t) on reliability cannot be overlooked. Shannon's capacity cannot be applied to characterize the probability of transmission error.[14] When determining the maximum achievable throughput for uRLLC applications, we must take into account the relation between the achievable throughput in the finite block length scheme and also the probability of transmission error as follows:[14,15]

$$C_k(\tau_k) = T_{tx} B_k(\log_2(1 + SINR_{jk}) - \Delta) \text{ bit/frame}, \tag{14}$$

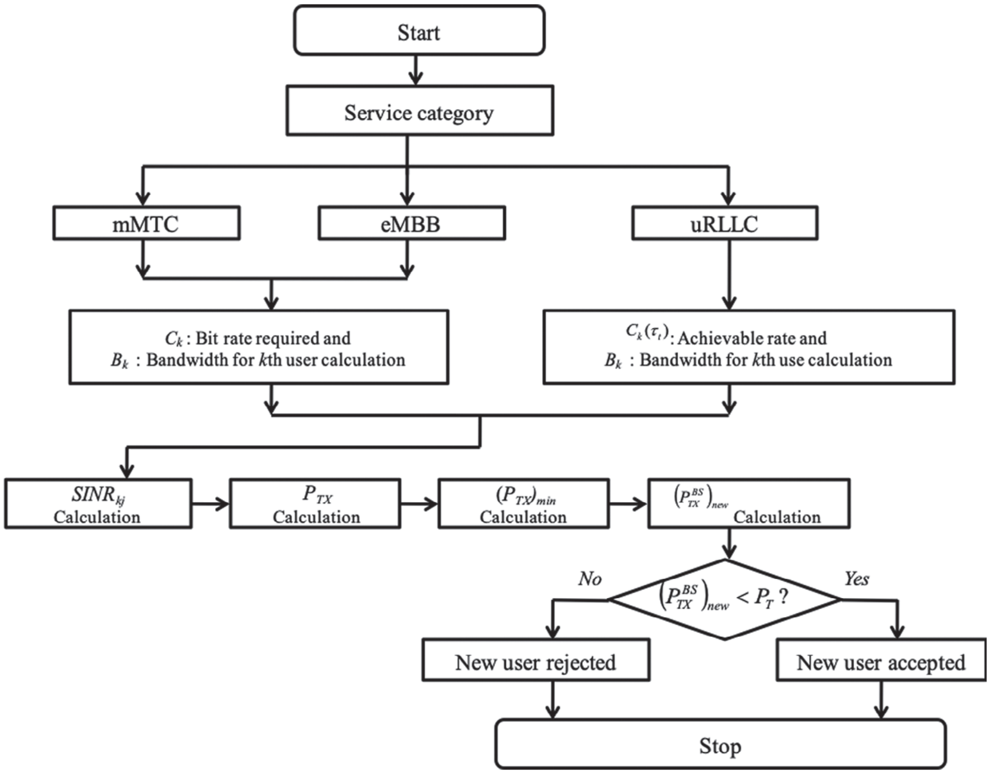

FIGURE 4 Flow chart of the simulation model

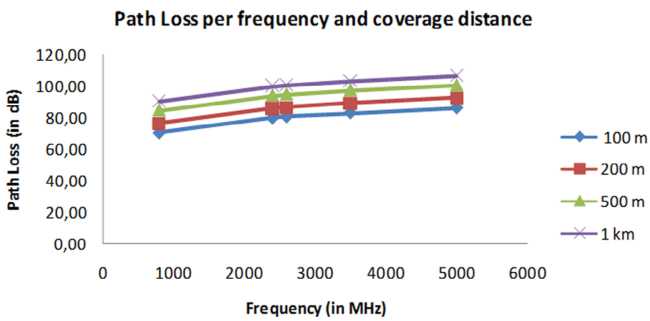

FIGURE 5 Path-loss per frequency and coverage distance

TABLE 1 Path loss (in dB) per frequency F (in MHz) and distance d (in m)

	Distance (m)			
Frequency (MHz)	100	200	500	1000
800	70.51	76.53	84.49	90.51
2400	80.05	86.07	94.03	100.05
2600	80.75	86.77	94.73	100.75
3500	83.33	89.35	97.31	103.33
5000	86.43	92.45	100.41	106.43

where $\Delta = Q^{-1}(\tau_t)\sqrt{\frac{V(SINR_{kj})}{T_{tx}B_k}}$ and $INR_{kj} = \frac{\alpha_k P_{TX} g_k}{I+N_0 B_k}$ and $C_k(\tau_k)$ is the maximal achievable rate of the kth user, B_k Total bandwidth for kth user equipment UE_k, N_0 is the noise power spectral density, and T_{tx} is the transmission duration (block length). It is the duration for downlink transmission in one frame. Q^{-1} is the inverse of Gaussian-Q function (called also Marcum-Q function), which id defined as:

$$Q(x) = \frac{1}{\sqrt{2\pi}}\int_x^{+\infty} e^{-\frac{t^2}{2}}\,dt \quad \text{and} \quad v(x) = 1 - \frac{1}{(1+x)^2}.$$

According to Khorov et al.,[14] in the case where the value of $SINR$ exceeds 10 dB, $V(SINR_{jk}) = 1$ is can be retained. Even when the $SINR$ does not exceed this value, we can obtain a lower limit of the achievable rate by taking $V(SINR_{jk}) = 1$ in the relation giving C_k. Hence, Equation (14) can be written as:

$$C_k(\tau_k) = T_{tx}B_k\left[\log_2(1 + SINR_{jk}) - Q^{-1}(\tau_t)\frac{1}{\sqrt{T_{tx}B_k}}\right]. \tag{15}$$

Which give, after calculation, $SINR_{jk}$ as:

$$SINR_{jk} = 2^{\eta} - 1, \tag{16}$$

$$\eta = \frac{C_k(\tau_k) + Q^{-1}(\tau_t)\sqrt{T_{tx}B_k}}{T_{tx}B_k}. \tag{17}$$

On the other hand, we consider:

$$SINR_{jk} = \frac{\alpha_k \frac{P_{TX}}{PL_{jk}} g_k}{I + N_0 B_k}, \tag{18}$$

where P_{TX} is the transmitted power and α_k is the average channel gain that captures path loss and shadowing (large-scale channel gain), g_k is the normalized instantaneous channel gain (small-scale channel gain), and I is the total interference (note that in case of using frequency division duplex mode (FDD), there is no interference between uRLLC users (i.e., $I = 0$).

Hence, we deduce P_{TX} like:

$$P_{TX} = (2^{\eta} - 1)(I + N_0 B_k)PL_{kj}. \tag{19}$$

Therefore we can again conclude here that to serve a UE which requires a minimum bit rate $(C_k)_{min}$, with the required QoS, the cell must consume therefore a minimum transmission power $(P_{TX})_{min}$, with:

$$(P_{TX})_{min} = (2^{\eta}_{min} - 1)(I + N_0 B_k)PL_{kj}, \tag{20}$$

such as

$$\eta_{min} = \frac{(C_{TX}(\tau_t))_{min} + Q^{-1}(\tau_t)\sqrt{T_{tx}B_k}}{T_{tx}B_k}. \tag{21}$$

This new UE will be accepted to join the network only if $(P_T^{BS})_{min}$ does not exceed the maximum power consumed by the relevant BS. Otherwise, this new user will be denied access to the cell.

The power consumption of a base station depends on its type, namely femto, pico, micro, and macro base stations, differentiated based on their coverage sites.[16] For instance, the maximum power of an MRRH is 20 W and for a small cell RRH 200 mW.[16] These values depend on the type of BS deployed in the cell. It can be considered that the computation power consumes almost 50% of the energy at 5G small cell base stations (see Figure 6).

The power consumption of 5G small base station (RRH) can reach 800 W when a massive MIMO (e.g., 128 antennas) is deployed to transmit high volume traffic.[17-19] In Table 2, we have estimated parameters by BS type used for our simulation.[14]

The total power consumed by each BS type is calculated in Table 3.

Figure 7 shows power consumed per each user (in mW), according to throughput requested by each user (in Mbps).

5G could be particularly energy-intensive. This new mobile technology standard could need more consumption of smart-phones battery and also multiply by three the power consumption of base stations.[20,21]

The carriers are orthogonal to reduce the gap between them and prevent the signals from interfering with each other and cancel each other out. This allows in particular, increasing the transmission bit-rate while using the spectrum to the maximum.[22]

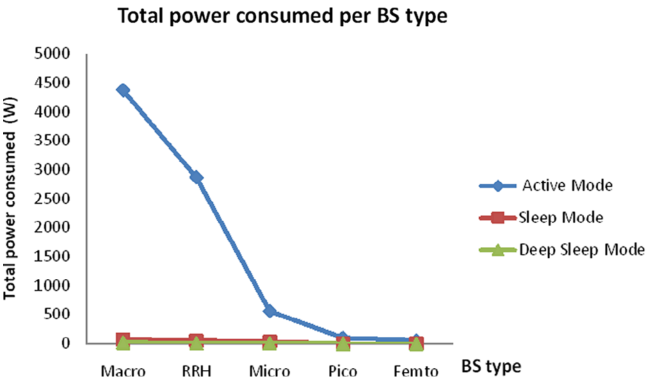

FIGURE 6 Total power consumed per BS type

TABLE 2 Estimated parameters by BS type

	BS type				
Parameter (*)	Macro	RRH	Micro	Pico	Femto
N_{TX}	6	6	2	2	2
P_{max} (W)	20	20	6.3	0.13	0.05
P_0 (W)	130	84	56	6.80	4.80
P_{SM} (W)	75	56	39	4.30	2.90
P_{DSM} (W)	21.75	16.24	11.31	1.24	0.84
N_{Sect}	1	1	1	1	1
N_c	4	4	4	4	4
P_{TX} (W)	20	20	10	5	1
P_{fL} (W)	2	2	2	2	2
P_{PA} (W)	40	20	6.30	0.13	0.10

TABLE 3 Total power consumed per BS type (in W)

	BS type				
Service mode	Macro	RRH	Micro	Pico	Femto
Active mode	4377.60	2872.80	564.68	105.87	60.04
Sleep mode	75	56	39	4.30	2.90
Deep sleep mode	21.75	16.24	11.31	1.25	0.84

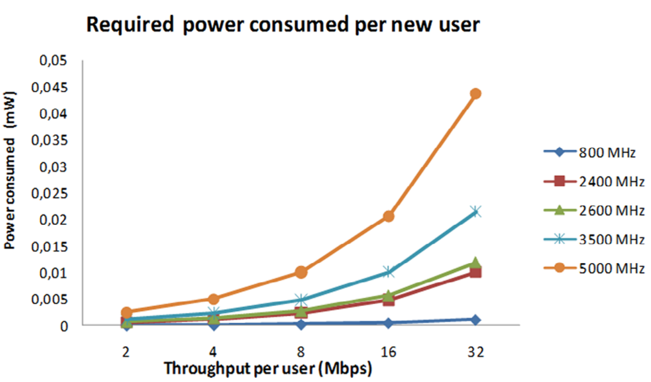

FIGURE 7 Power consumption per user

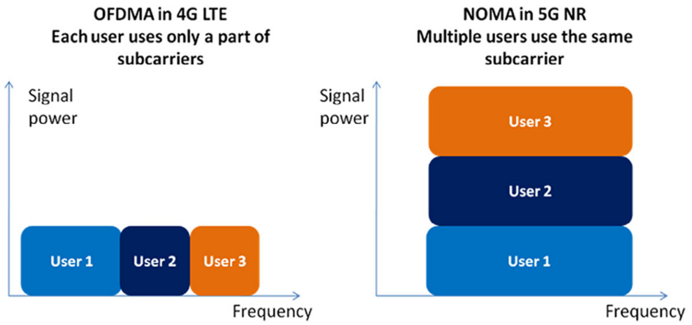

FIGURE 8 NOMA and OFDMA access modes

The result requires that each receiver and transmitter be able to receive and produce a lot of energy at the same time. Rather worrisome when we know that the 5G will push data consumption and require a lot of small antennas to connect all objects and ensure the propagation of millimeter waves.

Fortunately, the 5G will be very gradually deployed. It should mainly concern at first only consumers' smart-phones and not necessarily in the highest frequencies. Therefore, it is hoped that new, more energy-efficient methods will be found under 3GPP's Release 16 by 2021. This release recommends using nonorthogonal multiple access (NOMA), which can deliver the advantages of OFDM while also overlapping users on the same spectrum (Figure 8).

A working group of the 3GPP consortium is working on the subject. But this would require operators to update their base stations software and may even change their receivers. Therefore, mobile network operators (MNO) must be prepared to incur new more expenses because base stations would need software updates to handle NOMA.

The MNO needs to deploy advanced receivers, more processing power, and eventually other hardware upgrades.

Nonorthogonal access technique makes it possible to serve several users simultaneously and with the same frequency resource while reducing interference. Therefore, it allows increasing the number of users served simultaneously and supports massive connectivity and very low latency.

5 | 5G PROPAGATION MODELS

Without any physical connection or wires, the baseband signal is transmitted from the base station's antenna to the antenna of the user equipment. Hence, the signal transmitted meets usually some attenuation problem in the channel between the transmitter and the receiver. The transmitted signal strength can be significantly reduced as a function of distance due to factors related to the nature of the terrain (e.g., mountain, building, trees).

The prediction (i.e., calculation of the path loss) of the signal strength and the measurement is critical in estimating the mobile radio performance. Therefore, accurate estimation of radio path loss is quite essential for predicting coverage area (in terms of coverage radius calculation) of the base station and network capacity (i.e., number of served users or the surface of covered area). Therefore some mathematical algorithms are used to estimate and predict the propagation path loss.

A lot of used models exist and are grouped under three: Empirical models, semideterministic models, and deterministic models. Each model is applied in particular conditions in terms of frequency used, type of terrain, highness of obstacles, and so on. All frequency bands are determined in the World Radiocommunication Conference (WRC-19) held in 2019.[23] Finally, these models can be used after suitable calibration to adapt to the considered area.[24]

Generally, models used include the exponent model, which states that the attenuation is proportional to d^n, where d represents the distance and n a parameter that varies according to the geometry of the concerned area. In the case of wireless communications by radio waves, n is between 2 and 6, and generally close to 2 in outdoor.

6 | SOME APPLICATIONS FOR IOT AND TACTILE INTERNET

ITU recommendation (Rec.ITU-T Y.2060) gives an overview of the Internet of Things (IoT). According to ITU, a thing belongs to two worlds: the physical world (as a physical object) and the information world (as a virtual object), which can be able to be identified and integrated into communication networks.[25-27] Through the exploitation of identification, data capture, processing and communication capabilities, the IoT makes full use of things to offer services to all kinds of applications, while ensuring that security and privacy requirements are fulfilled.

IoT can be seen as a vision with both technological and societal implications.[28]

The IoT is a network of things, connected to improve the performance of day-to-day life and incorporates different kinds of resource-constrained devices like implantable, wearable, external devices, and autonomous vehicles.[29]

Medical research surveys indicate that about 80% of the people aged 65 years and over suffer from at least one chronic disease.[30,31] To connect these objects, some mobile networks (4G LTE) are used such as LTE-M (LTE for machine-type communication) and NB-IoT (narrowband IoT), which are LPWA technologies (low power wide area) standardized by 3GPP.

There are also other used LPWA technologies such as LoRa, Sigfox. The 5G technology enhances existing cellular use cases and expands to a new area of use cases and scenarios; massive IoTs, smart homes, smart cities, smart transportation, smart grids, intelligent autonomous, and self-driving vehicles.[32]

Some existing solutions to meet the increasing demand include the deployment of heterogeneous networks involving macrocells and small-cells (picocells, femtocells, etc.) distributed antenna systems (DAS) for Indoor communication, or relay stations. One of the requirements of a lot of IoT scenarios is the very low power consumption for a device that only exchanges (transmit and receive) very small volumes of data. There are many intervals of time during which the device does not exchange any data. If the device does not need to respond immediately to data sent to it, there is no need to keep the radio module running all the time.

Concerning services, applications, and requirements, the IoT market is divided into two categories: mMTC (Massive Machine-Type Communication) and uRLLC (Ultra-Reliable and Low Latency Communication). Smart Wearables and sensor networks are two examples of industrial domains belonging to the mMTC category.

A common use case is the measurement of health-related parameters such as body temperature and heartbeat. In the near future, the number of devices per person will create new requirements on the capacity needed to support these devices by cellular networks providing IoT services. Also, the extra cost for a wearable to be connected must be extremely low to attract a large number of consumers.

Sensor networks concern, for example, gas, water, and electricity meters. Potentially, each home is equipped with a multitude of sensors and meters that will put a high requirement on the communication system's ability to provide them with connectivity. Because energy meters are associated with stringent coverage requirements that consume radio resources, it is even more difficult to provide them with sufficient capacity. The meters can only rely on the energy supplied by their battery, which will impose high energy efficiency requirements of the device to operate for years on small batteries inexpensive. Also, uRLLC can be illustrated by several of applications such as autonomous driving, industrial automation and health and tactile Internet, which demands a very short latency duration and very stringent reliability. Autonomous driving requires vehicles connected to cellular communication networks that must offer ultra-reliability combined with extremely low latency.

Many research groups have worked to improve the smart grid concept, and many reference works, standards, laws, and applications have been developed. The energy market and utility grid operators have grown the use of renewable energy sources to manage the increased demand of the customer side.[33]

The call admission control (CAC) method suggested in this article aims to ensure massive connections of different objects and mobile devices (things) with minimum energy consumption. This allows very small 5G cells to serve a huge number of connected objects while guaranteeing a better quality of service.[34,35]

7 | CONCLUSION

Nowadays, many services such as the Internet of Things and Tactile Internet are becoming a reality thanks to the use of small equipment, devices, and sensors. In a 5G ultra-dense and heterogeneous network (HetNet), the need to connect many objects and mobile devices require the deployment of a large number of cells to respond to increasing data rates, without degrading the quality of service. Energy consumption will, therefore, also considerably increase. To minimize this waste of energy, the various research studies for call admission control (CAC) mainly focus on network capacity and coverage availability.

In this article, we have shown that this waste of energy can also be avoided by limiting the massive access of devices to the network according to the constraints on the total power consumed by small cells attached to macrocells in a heterogeneous system, without degrading the quality of service. Particular importance is given to devices that consume only small energy, and this, in the case of using the three types of 5G services, namely mMTC, eMBB, and uRLLC.

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