Wireless Device Power Savings in 5G

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Advancements in battery technology continue to be slow compared to increasing data rate and bandwidth demands of fifth-generation (5G) cellular technology such that battery life could become a bottleneck for 5G. Power saving techniques are therefore vital to the success of 5G. This article gives a brief introduction to many of these power savings techniques.

1. The Need for 5G Power Savings Techniques

The new 5G cellular technology is designed to support various and new industrial use cases, such as enhanced mobile broadband (eMBB), ultra-reliable and low latency communication (URLLC), massive machine type communication (mMTC), and vehicle to everything communication (V2X). These use cases require highly challenging quality of service metrics such as peak data rate, latency, reliability, availability, coverage, bandwidth, and a number of connected devices [1]. Compared to previous generations of cellular technology, 5G may require up to 20 times faster data rates, 20 times wider bandwidth, 10 to 100 times more connected devices, 99.999% availability, reduced bit error rates on the order of 10−5, and more ubiquitous coverage.

The enhanced data rate requirements of 5G require wireless devices with faster processing speeds that support larger bandwidths and more aggregated carriers. Low latency requirements of 5G further challenge wireless device capabilities. For example, wireless devices need to operate in higher subcarrier spacing environments with faster baseband processing. Wireless devices further need to receive control channels more frequently and with lower latency for receiving/transmitting data.

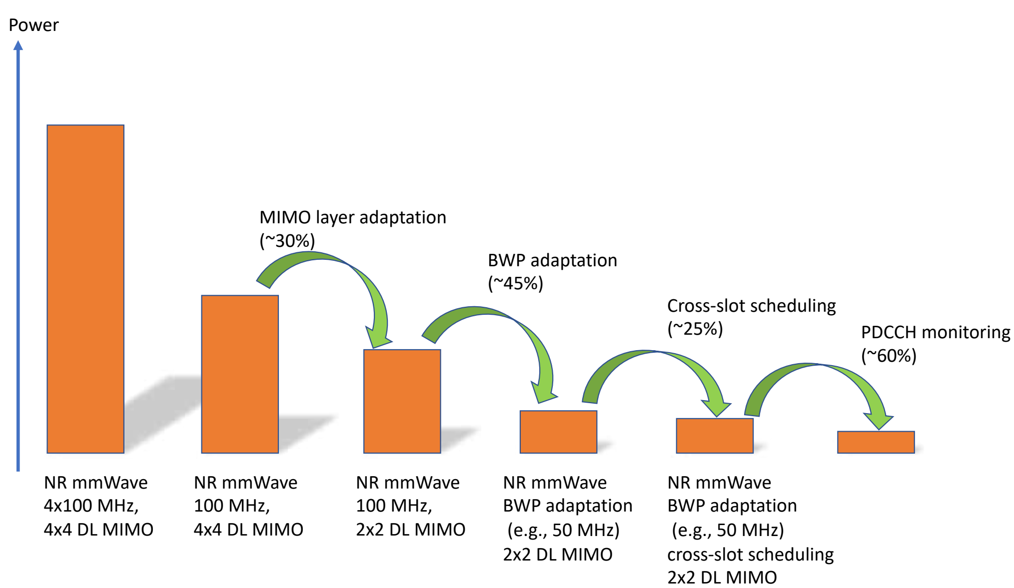

FIG. 1 Power Consumption Example

Overall, 5G wireless devices require increased hardware complexity (e.g., a massive number of antennas), higher processing power (e.g., 10 times faster than previous generations) and more processing (e.g., more frequent control channel receptions), which exponentially raises power consumption. Advancements in battery technology continue to be slow compared to the increasing data rate and bandwidth demands of wireless communications such that battery life could become a bottleneck for 5G technology.

Inefficient energy consumption leads to poor user experience. For example, according to a MediaTek survey [2], more than 70% of customers prefer longer battery life over better service quality of mobile devices. Moreover, an LG survey [3] shows that 9 out of 10 people felt panic when their wireless device battery level drop below 20%. These surveys show that smart power consumption and energy efficiency are keys for the success of 5G technology.

2. 5G Power Savings Techniques

New Radio (NR), the radio access technology of 5G technology, improves battery efficiency and achieves power savings through various techniques.

For example, NR reduces transmission power by adopting small cells instead of macro/large cells in at least some network deployments or coverage areas. NR further enhances efficient operation of time division duplexing (TDD) mode (where a device performs communication in one of the uplink or downlink directions at a time), which reduces power consumption compared to frequency division duplexing (FDD) mode (where a device simultaneously performs communication in both the uplink and downlink directions).

NR also provides for bandwidth part (BWP) switching, where a device is configured with a plurality of downlink and/or uplink BWPs with different bandwidth sizes. The base station and the wireless device can dynamically activate a BWP among the configured BWPs depending on demands such as traffic patterns and channel conditions. For example, a wireless device can be configured with a default BWP, which is generally configured with a smaller bandwidth compared to other BWPs, and can be autonomously switched to the default BWP when there is not much traffic/activity present. BWP switching has been shown to improve power consumption efficiency up to 45% [4].

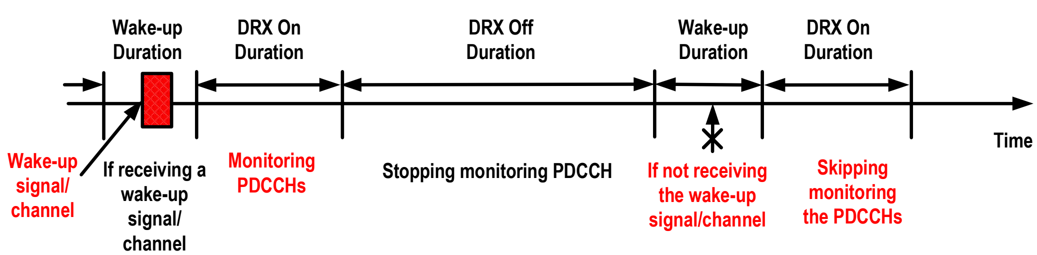

FIG. 1A

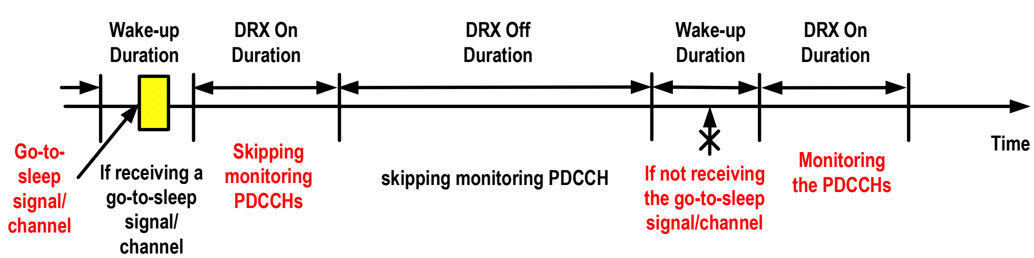

FIG. 2 Wake-Up/Go-to-Sleep Assistance

Moreover, NR also supports a new Radio resource control (RRC) state referred to as RRC INACTIVE. This new RRC state offers similar power saving functionalities as the RRC IDLE state. RRC INACTIVE state improves upon the RRC IDLE state by providing a lower overhead for the wireless device when transitioning back to the RRC CONNECTED state.

Similar to Long Term Evolution (LTE), a connected Discontinuous Reception (DRX) mode is supported in NR. A wireless device that supports DRX can repeatedly sleep and wake-up (e.g., during an Active Time) in a periodic manner. A DRX cycle can be configured for a wireless device by a base station, where the base station can configure a different cycle pattern depending on various aspects such as traffic demands, UE capabilities, UE battery status, etc. DRX can reduce power consumption considerably while the device is asleep.

In a nutshell, 5G power savings techniques aim to make a wireless device go to sleep (e.g., deep sleep, micro-sleep), reduce the number of active serving cells (e.g., secondary cell [SCell] dormancy), reduce active wireless device capabilities (e.g., reduce the number of active antennas), and maintain a small active bandwidth (e.g., by switching between small and large BWPs) as much as possible when there is no or low active traffic. FIG. 1 illustrates the possible reduction in power consumption with the adoption of successive NR power saving techniques, such as adapting the number of multiple-input-multiple-output (MIMO) antenna layers, adapting carrier bandwidths using BWPs, using cross-slot scheduling, and reducing physical downlink control channel (PDCCH) monitoring. Further details of these power savings techniques are discussed below.

2a. Wake-Up Signaling (DRX Enhancement)

Even with a DRX configuration as discussed above, analysis has shown that a major component of a wireless device's power consumption is spent monitoring control channels [5]. For example, a wireless device may spend more than 50% of its baseband power on monitoring control channels, whereas only about 20% of its baseband power is used to receive or transmit actual data. This indicates that there is still a considerable amount of additional power savings achievable during the Active Time of the wireless device.

There are current discussions on enhancing the DRX technique with a wake-up signal functionality. A wireless device wakes up all active serving cells on the active time of the DRX cycle. When a wireless device is configured with a large number of serving cells, the wireless device may still unnecessarily waste power during the active time, particularly when the wireless device is not expecting a high volume of data. For power savings, the wireless device can stay asleep even in the active time if there is little or no traffic. A base station can send

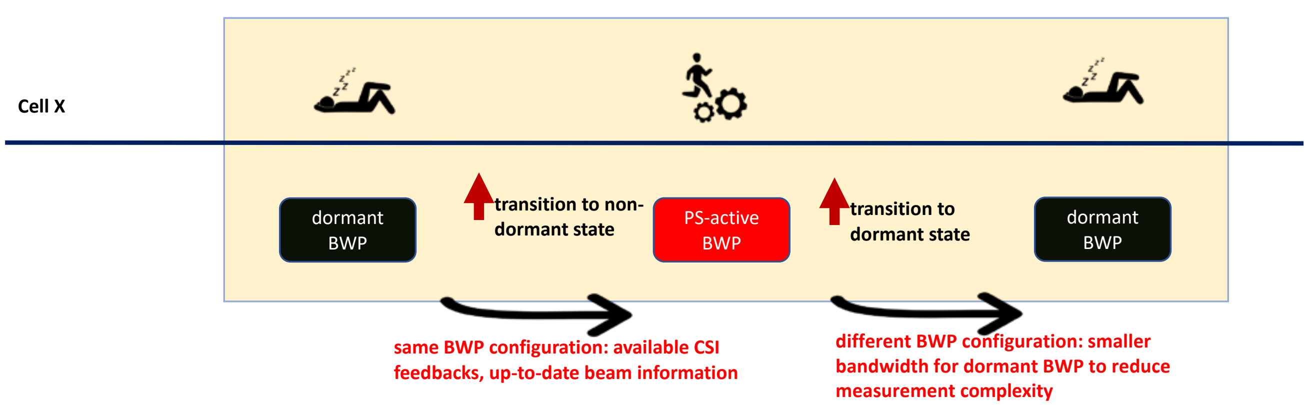

FIG. 3 Dormant SCell Mechanism

an assistance signaling to the wireless device to command the device to wake-up or go-to-sleep before an active time of a DRX cycle. The wireless device can wake-up and switch to the active time or can stay in sleep until the next DRX cycle as illustrated in FIG. 2.

2b. PDCCH Monitoring Reduction/SCell Dormancy

As shown in [5], a significant portion of baseband power consumption is used for monitoring control channels, such as PDCCHs. When SCell dormancy techniques are implemented, a base station dynamically enables or disables PDCCH monitoring on an SCell. The base station can transition an SCell to a dormant state when it has little or no traffic and can transition the SCell back to a non-dormant state when it has a higher traffic load. Dynamic enabling/disabling of PDCCH monitoring on an SCell allows for faster transitioning of an SCell between a dormant and non-dormant state such that any increase in latency from not monitoring PDCCHs is reduced. The wireless device does not monitor any control channel in a dormant SCell so that power consumption on PDCCH monitoring is minimized in the SCell. With keeping PCell non-dormant always, the wireless device can dynamically switch serving secondary cells between dormant and non-dormant states.

A wireless device receiving an indication to transition an SCell, such as Cell X in FIG. 3, to dormant state switches to a dormant BWP of the SCell. The wireless device switches to a non-dormant BWP (e.g., PS-active BWP) when it receives a subsequent indication to transition the SCell to a non-dormant state. The base station configures a dormant BWP and a non-dormant BWP from downlink BWPs of the SCell.

2c. Cross-Slot Scheduling

Cross-slot scheduling is adopted to reduce unnecessary wireless device buffering. A wireless device starts to buffer an entire bandwidth of an active downlink BWP for potential data scheduling by a base station at the start of a control channel monitoring (e.g., a search space occasion). This is because data can be scheduled by a downlink control information (DCI) via control channel monitoring as early as the starting of the monitoring. When the wireless device is not fully active, there is a high probability that there is no data scheduled in the search space occasion. This leads to unnecessary data buffering as there is no data scheduled for the wireless device. To avoid such buffering, cross-slot scheduling is adopted to ensure a minimum gap between a control channel and corresponding data. Based on the minimum gap between the control channel and the corresponding data, the wireless device is not required to buffer data during the minimum gap. The wireless device is not required to buffer data after the minimum gap when the UE has not received any scheduling DCI on the search space occasion. This procedure is illustrated in FIG. 4. This procedure reduces data buffering when the wireless device is not scheduled with data.

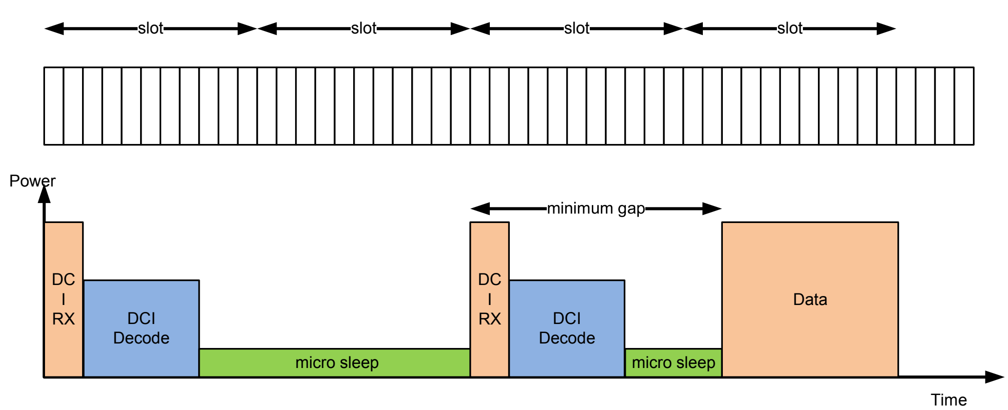

FIG. 4 Cross-slot scheduling

2d. Other Techniques and Future Enhancements

Power consumption can be further reduced by dynamically controlling MIMO transmission parameters. For example, a wireless device can be indicated with a maximum MIMO layer configuration via a BWP switching framework. A wireless device can be configured with a maximum layer for each downlink BWP. By switching from one BWP to another BWP, the wireless device may be configured with a different number of maximum MIMO layers. With a reduced number of maximum MIMO layers, the wireless device turns off some of its radio frequency (RF) components in transmit and receiver chains and reduces power consumption.

Although these techniques provide a good start, further power savings enhancements are still needed and will be discussed in future releases of 5G. For example, enhancements in RRC IDLE power saving, such as reducing power consumption for receiving a paging indication, will be discussed in 3GPP Release 17. Moreover, measurement relaxation, such as providing tracking reference signals for RRC INACTIVE and indoor devices, may be further discussed.

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