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Transmit power setting based on dynamic SAR

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ABSTRACT

Emitted power from consumer devices is required to meet a specific absorption rate (SAR) limit. Since SAR limits apply to the total transmitted power, mobile devices that have multiple radios limit transmit power on each radio based on the on/off status of other radios. For example, if cellular is enabled, then the maximum power available to WiFi is reduced. Such an approach does not account for the actual instantaneous power transmitted by a radio. For example, the cellular radio may be transmitting well below its maximum power when proximate to a base station. In such a case, the WiFi (or Bluetooth) radios can safely transmit power at relatively high levels while staying with the SAR limit.

The techniques of this disclosure calculate the maximum transmissible power of a radio based, e.g., on the actual power transmitted by other radios; on the priority of different radios; on the scheduling of packets within each radio; etc. The techniques thereby can achieve a higher per-radio transmit power, e.g., higher link throughput, while operating within the SAR limit.

KEYWORDS

- Specific absorption rate (SAR)
- Mobile emission
- Transmit power
- Radio emission
- WiFi
- Bluetooth
- LTE

BACKGROUND

To ensure public health, regulators in different countries, e.g., the federal communications commission (FCC) in the United States, specifies rules for consumer devices, e.g., restricting radio emissions to meet or better a specific absorption rate (SAR) limit. Since SAR limits apply to total transmitted power, mobile devices that have multiple radios, e.g., cellular (3G/4G/LTE), WiFi, Bluetooth, etc., limit transmit power on any one radio based on the on/off status of other radios. For example, if cellular is enabled then the maximum power available to WiFi is reduced. Typically, a table indicates the maximum transmissible power on any one radio when some combination of radio channels is enabled. Additionally, other device states can be used to limit transmit power, e.g., if the phone is detected to be near the head or hand of the user, then transmit power is reduced, etc.

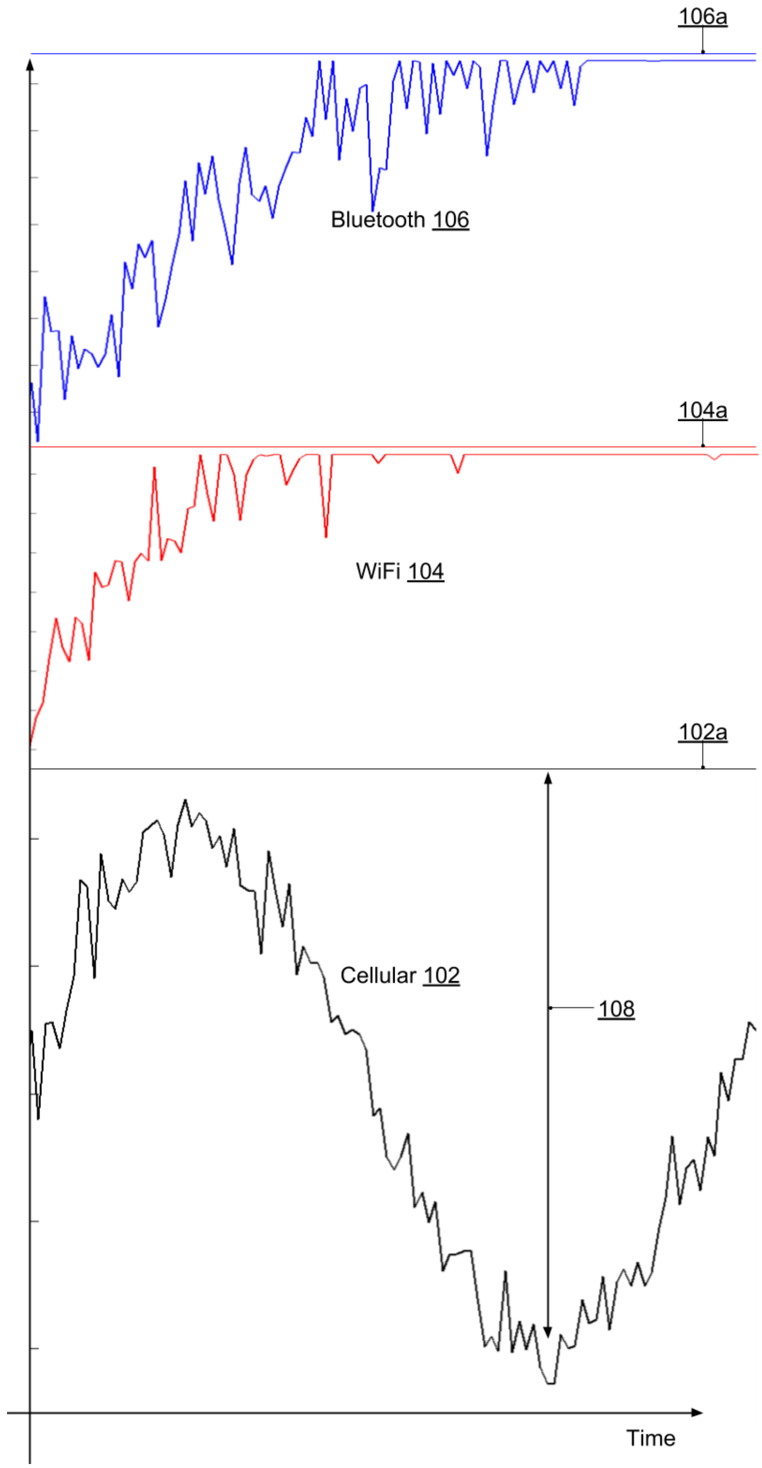

Fig. 1: A radio that does not take advantage of low actual transmit powers of another radio

There are several limitations with the current table-based approaches, as follows.

- **Tables do not account for the actual power transmitted by each radio:** This is illustrated in Fig. 1, which shows the power versus time waveforms for three radios, e.g., cellular (102), WiFi (104), and Bluetooth (106). A radio may be transmitting at less than full power, e.g., the power of cellular radio may be controlled down by its serving base station, the power of a Bluetooth radio may be controlled down by the headset, a WiFi radio may independently drop power, etc. In Fig. 1, the power of the cellular radio is well below its maximum transmissible power (102a), giving rise to headroom (108). Yet, the WiFi and the Bluetooth radios do not transmit beyond their respective maximum available powers (104a, 106a) such that transmission from these radios does not take advantage of the headroom created by the relatively low power of the cellular radio.
- **Tables do not account for use case:** Based on device usage, one radio may be more important to user experience than others. Tables do not account for situations, for example, where Bluetooth is of priority due to high usage, ongoing streaming of audio, and greater need for power. Neither do tables de-prioritize WiFi outdoors if a strong cellular signal is present.
- **Tables do not allow for per-packet optimization:** It may be beneficial to only reduce power when multiple radios are transmitting simultaneously. A static, table-based approach limits transmit power when a set of radios could transmit, even if they do not.

DESCRIPTION

The techniques of this disclosure calculate the maximum transmissible power of a radio based, e.g., on actual power transmitted by other radios; on the use case, e.g., priority, of radios; on the scheduling of packets within each radio; etc. The techniques thereby can achieve a higher per-radio transmit power, e.g., higher link throughput, while meeting or exceeding FCC limits.

Transmit power adjustment based on measurement of transmitted power

Some radio protocols, e.g., cellular, Bluetooth, etc., change power slowly. For example, a cellular base station controls the transmit power of the mobile device, causing the power to vary slowly. A coupled Bluetooth headset controls the Bluetooth power of mobile device. A WiFi transmitter calculates its transmit power based on the received signal strength (RSSI) of a WiFi access point, e.g., a strong RSSI results in low WiFi power, and vice-versa.

Per the techniques of this disclosure, the maximum power of a given radio of a device, e.g., WiFi radio, is calculated based on the actual current power of other radios, e.g., cellular and Bluetooth radios. Such maximum transmit power can be pre-computed and stored or can be computed on the fly.

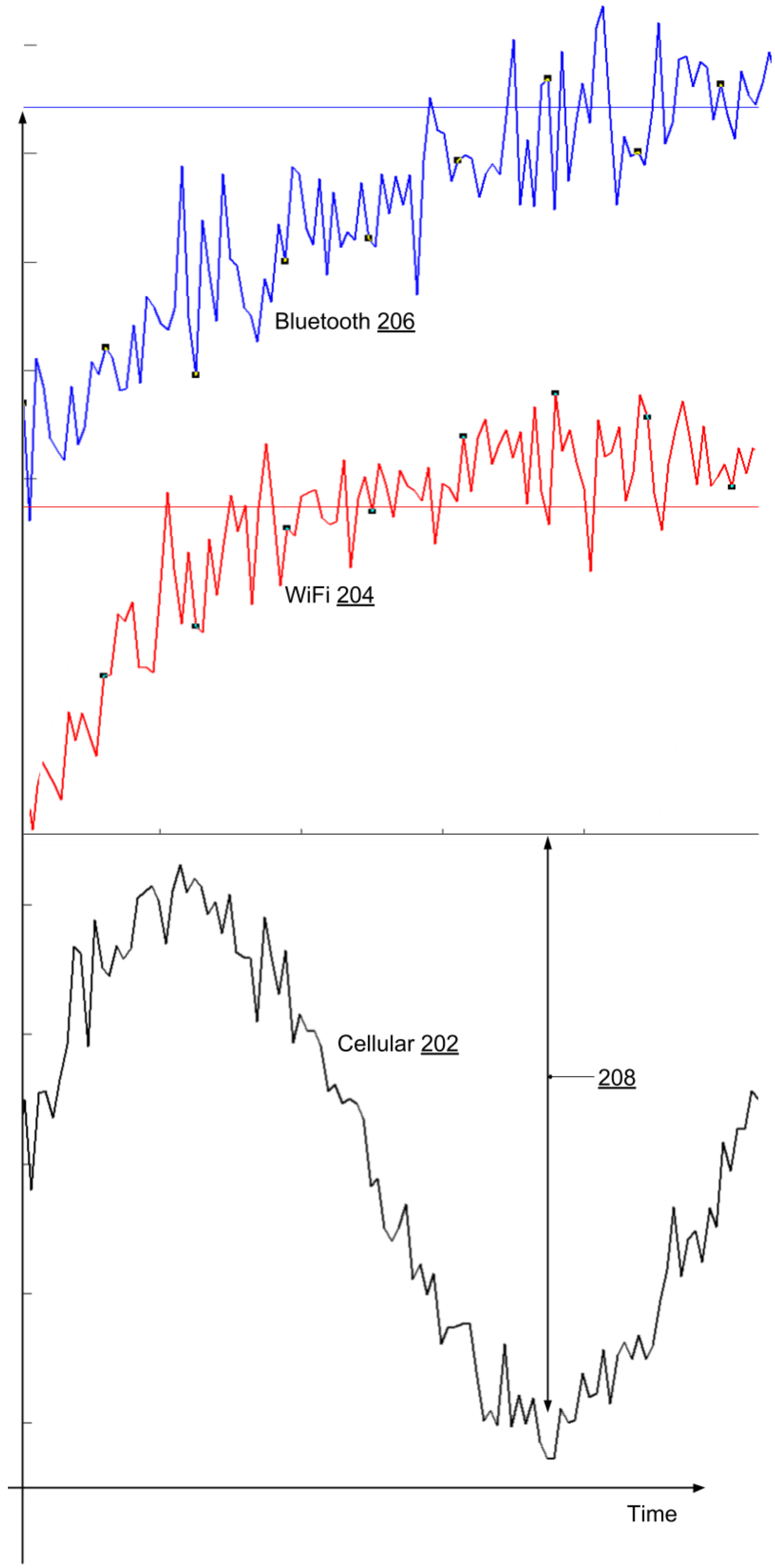

Fig. 2: Computing maximum power of a radio based on actual transmit power of other radios

Fig. 2 illustrates computing maximum power of a radio based on actual transmit power of other radios. In Fig. 2, the cellular radio (202) momentarily reduces its power, thus creating headroom (208). The WiFi (204) and Bluetooth (206) radios advantageously leverage this headroom to transmit at relatively high power levels, temporarily exceeding imposed limits. Despite the high power levels of WiFi and Bluetooth, the total transmit power of the mobile device as a whole conforms to regulations due to the momentarily low power of the cellular radio.

Transmit power adjustment based on use case

It is possible that at least one radio of a device has less transmit power allowance than its power demand. The techniques of this disclosure enable prioritization of radios based on use cases such that low priority radios are maintained in a relatively power-starved condition to ensure the link availability of higher-priority radios.

As an example, if a user is currently using a 2.4 GHz Bluetooth audio link while downloading a large file in the background over a 2.4 GHz WiFi, then the power allocation techniques momentarily prioritize Bluetooth, while maintaining the WiFi link on a best-effort basis. As another example, WiFi power is reduced if a mobile device is outdoors and if a strong cellular signal is present. Radios can be prioritized using coexistence techniques, e.g., techniques that detect, with user permission, use cases, in order to coordinate resource-sharing.

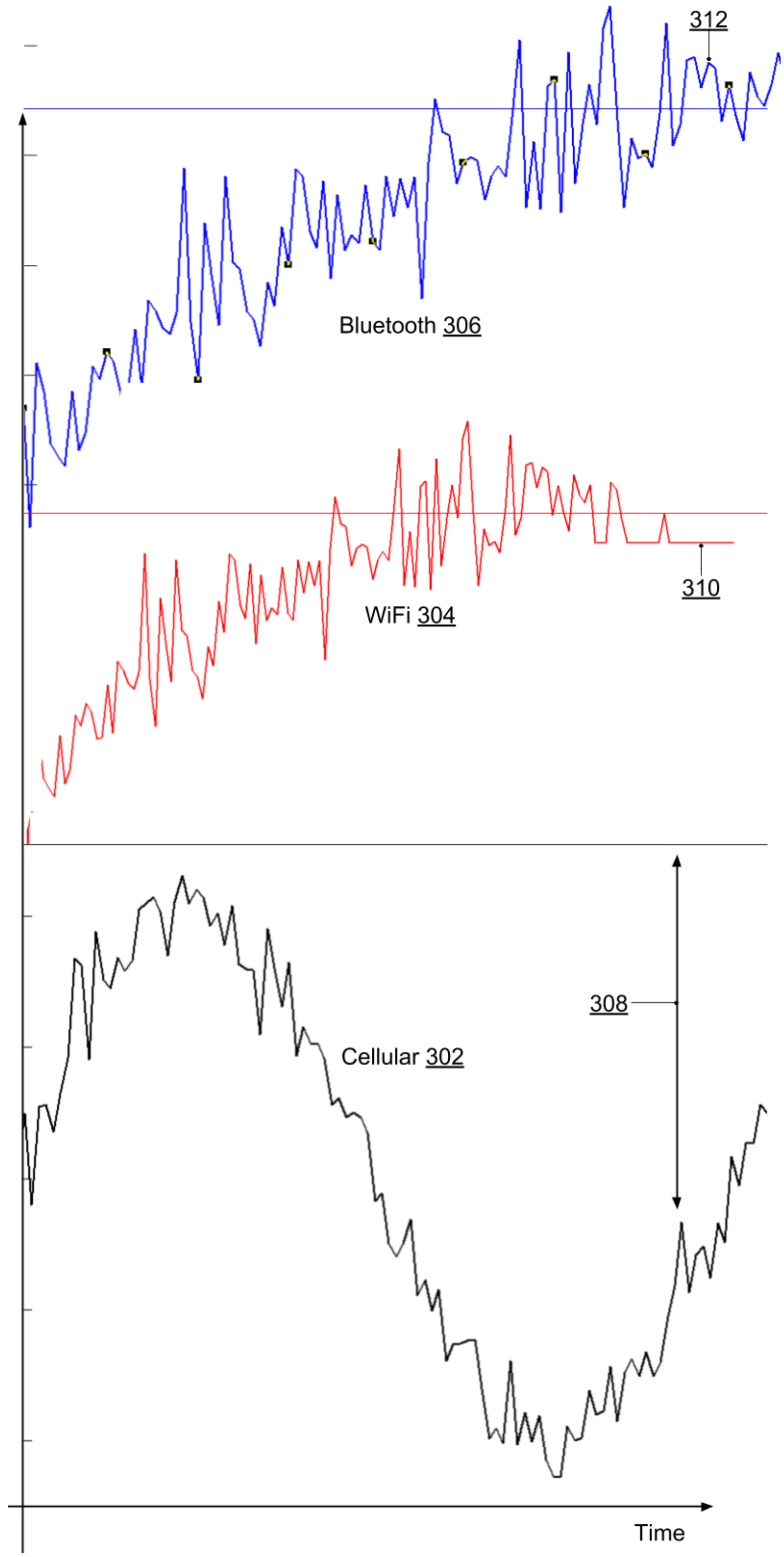

Fig. 3: Prioritization of radios based on use case

Fig. 3 illustrates prioritization of radios based on use case. After a dip, the cellular power waveform (302) rises, causing the headroom (308) to decline. In response, the WiFi and Bluetooth radios have less power to go between them. Bluetooth is prioritized, enabling its waveform (306) to maintain a relatively high power level (312), while WiFi is maintained on a best-effort basis, causing waveform (304) to saturate (310).

Power allocation on a per-packet SAR basis

To achieve greater total transmit power while still conforming to regulations, radios requiring backoff are backed off only if the transmissions are truly concurrent. For example, if transmissions are scheduled such that they do not overlap, then the transmissions proceed without backoff, e.g., at relatively high power. The mobile device (controlled by its operating system) determines concurrent and non-concurrent transmissions that are to occur in the near future by looking up scheduling information. The ability to transmit a relatively large power by look-ahead scheduling may be sufficient to maintain a link in some cases.

To coordinate with rate adaptation processes, two transmit-side rate-adaptation algorithms are run in parallel, one for SAR-limited transmissions and one for full power. Additionally, time-domain sharing can also be applied, e.g., a 5 GHz WiFi and a 2.4 GHz Bluetooth do not transmit simultaneously, while a 2.4 GHz WiFi and a 2.4 GHz Bluetooth share the radio medium.

With the trend of mobile devices becoming increasingly free of cables, e.g., the removal of the 3.5mm audio jack in lieu of Bluetooth audio, robust wireless performance is more important than ever. The techniques of this disclosure leverage a current state of the mobile device, e.g., the transmit power of its radios, the priority of different radios, the schedule of packet transmissions, etc., to maintain reliable, high-throughput links for on-board radios, e.g., cellular, WiFi, Bluetooth, etc.

Further to the descriptions above, a user may be provided with controls allowing the user to make an election as to both if and when systems, programs or features described herein may enable collection of user information (e.g., information about a user's social network, social actions or activities, profession, a user's preferences, or a user's current location), and if the user is sent content or communications from a server. In addition, certain data may be treated in one or more ways before it is stored or used, so that personally identifiable information is removed. For example, a user's identity may be treated so that no personally identifiable information can be determined for the user, or a user's geographic location may be generalized where location information is obtained (such as to a city, ZIP code, or state level), so that a particular location of a user cannot be determined. Thus, the user may have control over what information is collected about the user, how that information is used, and what information is provided to the user.

CONCLUSION

The techniques of this disclosure calculate the maximum transmissible power of a radio based, e.g., on the actual power transmitted by other radios; on the priority of different radios; on the scheduling of packets within each radio; etc. The techniques thereby can achieve a higher per-radio transmit power, e.g., higher link throughput, while operating within the SAR limit.