RTT TECHNOLOGY TOPIC
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Session power budgets

In this month's HOT TOPIC we consider 3G handset power budgets - how much power does a 3G handset consume, how much power (battery capacity) does a 3G handset have available, how and why power consumption and battery capacity together determine session length and session value.

(1) 3G HANDSET POWER CONSUMPTION

How much power does a 3G handset consume?

Well, it all depends:-

Let's consider uplink power consumption, and physical layer power drain.

Physical Layer Uplink Power Consumption

System Factor	Application Factors	Device Factors
Distance	Data structure	RF device capability
↓	↓	↓
RF power budget	RF power budget	RF power budget

Table 1: Physical Layer Uplink Power Consumption

The amount of RF power needed by the handset on the uplink is determined by its distance from the base station, which is determined by network density (a system factor). A Class 4 handset has a maximum transmit power of 125 milliWatts (equivalent to a GSM 1800 one Watt phone working on a 1/8 duty cycle); minimum required power may be a few milliWatts close to the cell.

You might also expect the RF power budget to increase with data rate. Actually occupied bandwidth increases with data rate rather than power budget but power budget is dependent on data structure, for example, if multiple OVSF code streams are supported on the uplink. This is because multiple code streams increase the peak to average ratio of the coded signal. This increases the need for linearity in the handset PA and by implication decreases handset power amplifier efficiency. This brings us to the choice of RF device. Even with the Class C amplifiers used in GSM, power efficiencies of better than 55% are very hard to achieve and as the need for linearity increases, power efficiency goes down. This can be offset to an extent by using materials such as silicon germanium but cost per Watt tends to be higher than traditional semiconductor solutions.

Physical Layer Downlink Power Consumption

Similarly, physical layer downlink power consumption is determined by system factors, application factors and device factors. As distance from the base station increases, coding overhead will tend to increase which means the handset channel decoder will need to work harder for a given user data rate which will be reflected as an increase in the baseband power consumed.

System Factor	Application Factors	Device Factors
Distance	Data rate and data structure	RF device capability
↓	↓	↓
RF power budget (additional coding overhead)	Baseband power budget	Baseband power budget

Table 2: Physical Layer Downlink Power Consumption

As data rate increases, channel decoder overheads increase, typically from about 700 - 900 MOPS (million operations per second) for a 384 kbit decoder to 3500 MOPS - 4000 MOPS for a 1920 kbit decoder. Use of multiple OVSF codes also significantly increases decoder overhead and places stringent demands on baseband device capability. A number of highly parallel processing architectures are presently being proposed to manage multiple channel decoding but some issues (for example, compiler efficiency), still need to be resolved. In addition, the baseband processing power budget needs to accommodate RRC filter overheads and any baseband compensation techniques incorporated in the handset design.

Application Layer Uplink Power Consumption

Application layer uplink power consumption is determined by application and device factors.

Application Factors	Device Factors
Audio bandwidth	Audio encoder power budget
↓	↓
Video bandwidth	CCD or CMOS imaging
↓	↓
Application bandwidth	MP4 encoding
↓	↓
Baseband power budget	Baseband power budget

Table 3: Application Layer Uplink Power Consumption

Application factors include audio bandwidth source coding - the additional MOPS needed in an AMR-W (adaptive multirate wideband) encoder to capture wideband audio. Video bandwidth is a product of resolution (number of pixels), colour depth and frame rate. Note that the choice of video bandwidth quality determines the choice of CCD (high quality high power consumption) or CMOS (lower quality lower power consumption) device used for image capture. The frame rate also determines the processor clock speed (and by implication, the application processor power budget). Application bandwidth is a product of the audio and image/video source coding and any other information streams included in the application multiplex (text for example). As application complexity increases, MP4 encoder overheads increase (and power consumption goes up).

Application Layer Downlink Power Consumption

Ditto with the downlink - audio decoder overheads increase as audio fidelity improves, image and video decoder overheads increase as image/video quality improves. The big hit on the downlink however, is the display - a high resolution high colour depth display is a power hungry device, a back light at full brightness on its own can consume nearly 500 milliWatts! It is important in this context to consider the impact of adding in Java games and sophisticated MMI (man machine interface) functionality. By the time a user gets round to making a call, his/her battery (and probably the user) will be completely exhausted - bad news for session value.

(2) GSM AND 3G HANDSET POWER CONSUMPTION COMPARISON

So let's take a standard GSM phone with a PA efficiency of 55%, a low power budget greyscale display and minimal application processing (other than voice). We could be looking at a call state power budget of typically 400 to 500 milliWatts. A 700 milliamp per hour battery at 3.6 volts gives 2.5 Watt hours of capacity or about 6 hours of user time.

A 3G phone will typically have a PA efficiency of 20 - 30%. This doubles the DC power budget for a given amount of RF power. Add on to the uplink power budget a couple of hundred milliWatts for the CCD or CMOS image sensor (and related processor overhead) and 200 to 500 milliWatts to the downlink budget for an MP4 decoder and high resolution high colour depth display, add on the extra overheads for the RRC filter and turbo decoder, a GPS receiver, a Bluetooth transceiver, an MP3 player and for good measure, high fidelity polyphonic ring tones. I'm up to 2 Watts and still counting.

(3) BATTERY DENSITY COMPARISONS

So all I need is a bigger better battery.

	Ni-Cads	**NiMh**	**Lithium Ion**	**Zinc Air**	**Lithium Thin Film**
Wh/kg	60	90	120	210	600
Wh/litre	175	235	280	210	1800

Table 4: Battery Density Comparisons

Table 4 shows that we can increase capacity by using more chemically exotic materials and/or new packaging techniques, ie higher capacity does not necessarily mean an increase in weight or size though does generally mean a (large) increase in cost. We also need these newer battery technologies to deliver good through life performance, be resilient to misuse, have low self-discharge rates and be environmentally acceptable. Additionally high density batteries like to hold on to their power (they tend to have high internal resistance). Given that we are trying to design adaptive bandwidth on demand handsets (that may be delivering 15 kbps in one 10 millisecond frame and 960 kbps in the next frame), then we need a battery that can support bursty energy needs.

Methanol cells may be a future alternative. These are miniature fuel cells which use methanol and oxygen with (usually) platinum as a catalyst. Fuel cells can potentially deliver better than 100% efficiency (as they pull heat from the atmosphere). Even the best diesel engines struggle to get to 30% efficiency so methanol cells with an energy density of 3000 Wh/kg would seem to be a promising way forward.

Motorola have a prototype direct methanol fuel cell (DMFC) which has a membrane electrode assembly, a fuel and air processing and delivery system, a methanol concentration sensor and a liquid gas separator to manage the release of carbon dioxide. The prototype measures 5 x 10 x 1 cm excluding the control electronics and fuel reservoir. However, the device can only presently produce 100 milliWatts of continuous net power so there is some way to go before we have a methanol multi-media mobile.

Potentially, however energy densities of over 900 Watt hours per kilogram are achievable. A 20 gram battery would be capable of producing 18 Watt hours of power.

(4) SESSION POWER BUDGETS

In the meantime, we need to consider the impact of present battery limitations (output power and capacity) on session value.

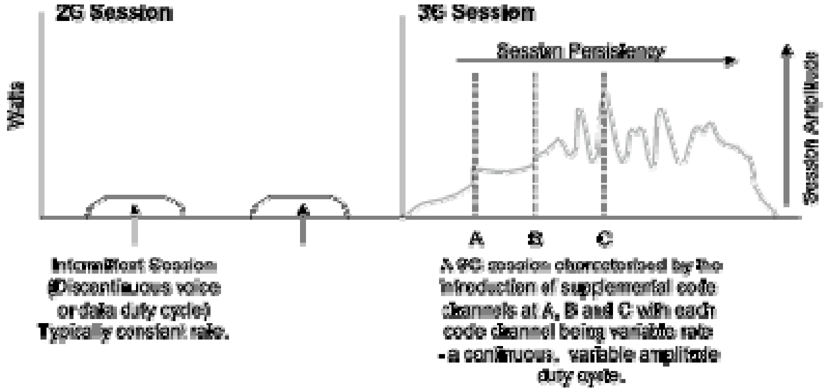

Figure 1: 3G Session Data Duty Cycle

Figure 1 shows a 3G session compared to a 2G session. A 2G session will typically exhibit a discontinuous duty cycle - occasional bursts of packet data or bursts of speech (if using voice activity detection).

In a 3G session, the objective of the application layer software (see our November HOT TOPIC on Session Management) is to introduce additional code streams each of which may be variable rate. The effect is to produce a continuous variable amplitude duty cycle. The session may also be multi-user to multi-user which adds additional session complexity. As session complexity increases, session persistency (session duration) increases - we increase the size of the billable event (session value). We build up billable session value on the basis of experienceable quality metrics - audio fidelity, image and video quality (colour depth, resolution, frame rate) all of which add to bandwidth value except that … our battery goes flat.

(5) POWER BUDGETS AND SESSION VALUE - SUMMARY

Figure 2 illustrates two factors that we need to consider:-

(i) If we improve session quality (audio and image and video quality) and increase session complexity (multiple variable rate code streams) we increase session amplitude which in turn increases the drain on our battery. Note that the battery needs to be dimensioned to meet the peak power demands of the session which probably means maximum RF power and maximum baseband power - a lack of peak power capability will have the effect of 'clipping' session amplitude (and thereby degrading session value).

(ii) Power drain limits session duration. This degrades session value both in terms of user to user exchanges and multi-user to multi-user exchanges. It will be very depressing to have users leaving a multi-user to multi-user exchange because their battery has gone flat - it will tend to destroy the integrity of the session, and hence the value of a multi-user multi-media exchange. The relationship of battery drain, session amplitude and session duration is shown in Figure 2.

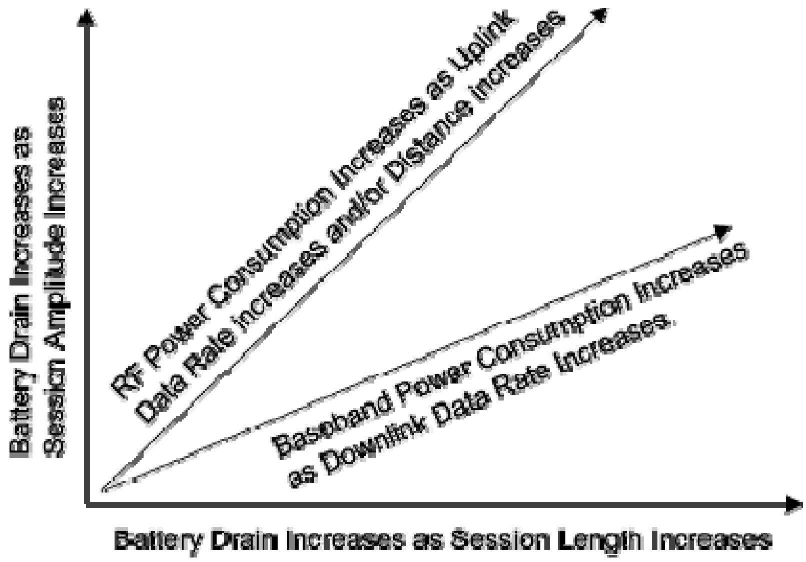

Figure 2: Battery Drain Metrics

(6) THE SOLUTION

There isn't one. Well, in fact, there are two:

(i) Increase RF device and baseband processor efficiency - this is an on-going design challenge and involves better (more exotic) RF materials and better (more complex) processor architectures (and associated compiling techniques). More efficient display technologies will also be of major importance.

(ii) Increase battery capacity and peak power capability.

In the meantime, we need to come to terms with the fact that power consumption and battery capacity constraints limit uplink and downlink traffic value.

Revenues in 2G networks are based on the fact that users can chat on their phones for hours at a time (the session persistency metric). To be fiscally successful, 3G networks will need to deliver similar user functionality - 'better batteries or bust'.

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