Wireless Wolrd Research Forum Meeting 20

22-24 of April 2008 in Ottawa, Canada

Meeting Agenda

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Wireless World Research Forum Meeting 21

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Meeting Agenda

Meeting Presentations and Papers

Power Consumption of Mobile and Wireless Thin Clients

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Abstract—**The thin client paradigm is regarded as a solution for running complex applications on mobile devices. In light of the current attention for energy efficiency it is important to review the power consumption of the thin client paradigm. We build an analytical model to estimate this power consumption and use experimental data to review these estimates. This is done for UMTS and wifi technology.**

Index Terms—**Thin Client, Power consumption, UMTS, wifi**

I. Introduction

Currently awareness is rising that the energy consumption is an important factor to consider in ICT technologies. This was already clear for mobile and wireless devices where low power consumption was required in order to maximize battery lifetime. At the moment it is however becoming clear that the global energy consumption of ICTs deserves attention as well. Currently the use phase represents approximately 8% of the worldwide electricity production. Moreover this fraction is expected to grow substantially in the near future. In light of the energy production limits and the growing attention for the related environmental concerns this growth is unsustainable. [1] [2]

In light of this unsustainable growth it is important to analyze the energy consumption of mobile and wireless applications. Currently the thin client paradigm is considered to enable resource-demanding applications on mobile devices. In the thin client paradigm the application runs on a remote server with high processing capacity. The input and output signals are transmitted over the network interconnecting the mobile device and the server.

When regarding the energy efficiency the thin client paradigm has some clear advantages but some drawbacks as well. Firstly, the servers on which the applications are running have a high number of resources. If we try to run as many sessions as possible on as little as possible servers it is clear that we are using the resources in the most optimal way. Secondly, the mobile devices will become less resource demanding since no complex applications need to run on them. This also assures longer life cycles since the resource demand is focused on the server.

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On the other hand the thin client paradigm requires a power-consuming network and server farm. It is important that the power consumption of these elements is kept under control.

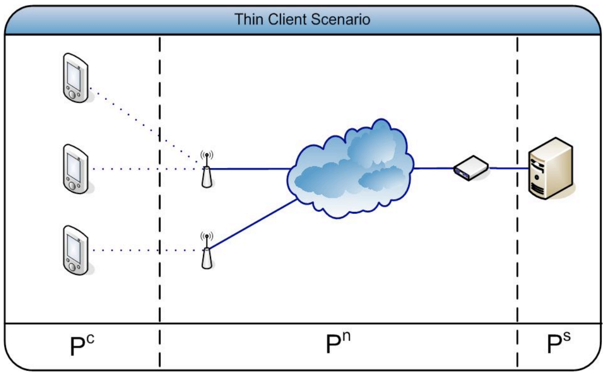


Fig. 1 Thin Client Scenario

In this paper we will consider two cases. In the first case a UMTS connection on a mobile network is used. In the second case we consider a wired access network using a wifi device to make the interconnection. We will build an analytical model to analyze the power consumption and based on real world data we will evaluate the model.

II. Analytical Model

In order to determine the power consumption we construct an analytical model based on the power consumption of the different components. This is displayed in Fig. 1.

A. Client Device

In the client device we consider three terms contributing in the power consumption. The first term is the basic power consumption P_0^c of the device. The second term is P_{CPU}^c, the power consumption related to the CPU processing. The third term is P_{NIC}^c the power consumption related to the network interface card (including the antenna).

The CPU power consumption depends on the CPU load λ_{CPU}^c, a figure between 0 (idle) and 1 (full load). The CPU load is caused by two processes. The first process is the actual processing power of the running application. Since most of the processing will be done on the remote server this fraction is negligible. The second process is the CPU load related to the network traffic.

$$P_{CPU}^c = f\left(\lambda_{CPU}^c(b)\right) \tag{1}$$

We consider this CPU load to be proportional to the bit rate b. Moreover, based on experimental measurements we assume the function relating the CPU load to the power consumption to be linear. This leads to:

$$P_{CPU}^{c} = P_{CPU,0}^{c} + \alpha_{CPU,T}^{c} b \tag{2}$$

The NIC power consumption can be broken down again in two terms. The first term is the power consumption due to the NIC connecting to the network this term will be proportional to the time fraction the NIC is active f_{act}. This time fraction is determined by the thin client protocol. The additional power consumption when the antenna is active is denoted as P_{act}^{c}. The second term is the power consumption related to the actual network traffic. This is again proportional to the bit rate *b*.

This leads to:

$$P_{NIC}^{c} = P_{NIC,0}^{c} + P_{act}^{c} f_{act} + \alpha_{NIC,T}^{c} b \tag{3}$$

Adding up all terms leads to the total power consumption of the client device. We incorporate the terms $P_{*,0}^{c}$ in P_{0}^{c} and add up the terms $\alpha_{*,T}^{c}$ to α_{T}^{c}.

$$P^{c} = P_{0}^{c} + P_{act}^{c} f_{act} + \alpha_{T}^{c} b \tag{4}$$

B. Server

On the server the actual application runs together with the thin client protocol supporting software. We consider a share ratio of N_s users per server. The power consumption is dependent on the load on the hard drive (HD), NIC and CPU.

$$P^{s} = \sum_{*=HD,CPU,NIC} f_{*}\left(\lambda_{*}^{s}\right) \tag{5}$$

Based on experimental measurements we assume linear dependencies. We add up the idle load power consumptions $P_{*,0}^{s}$ to P_{0}^{s}. Moreover we can neglect the term in HD load since the power consumption is heavily dominated by the rotor speed and not the actual load. We again assume the load dependent fraction of the NIC load to be proportional to the bit rate. This bit rate is equal to $N_s b$. This leads to:

$$P^{s} = P_{0}^{s} + \alpha_{CPU}^{s} \lambda_{CPU}^{s} + \alpha_{NIC}^{s} N_s b \tag{6}$$

The CPU load λ_{CPU}^{s} needs to be broken down further. This factor is determined by the average load λ_{CPU}^{app} a user application is causing on the server and the overhead ε caused by the thin client protocol. Since N_s users are causing this load we get:

$$\lambda_{CPU}^{s} = N_s\left(\lambda_{CPU}^{app} + \varepsilon\right) \tag{7}$$

This relation also implies a maximal value for N_s due to $\lambda_{CPU}^{s} \le 1$.

C. Network

The network power consumption is determined by the equipment of which the network consists. In the UMTS case the power consumption is caused by the Node B, RNC and UMSC. Since in a typical network more than 95% of the network consists of Node B-s we will only consider this element. The power consumption of the Node B is approximately constant and independent of the network traffic. This leads to a network power consumption per user of:

$$P^{n} = \frac{1}{N_{NB}} P_{0}^{NB} \tag{8}$$

TABLE I
EXPERIMENTAL PARAMETERS

Device	Parameter	Value
Client Device	P^{c}	6.52 W
Network (UMTS)	P^{NB}	6000 W
	N_{NB}	20
Network (Wifi)	P_{0}^{WLAN}	6 W
	P_{0}^{ADSL}	1.1 W
Server	P_{0}^{s}	217 W
	α_{NIC}^{s}	$0.93 \frac{mW}{Mbit/s}$
	PUE	2
	α_{CPU}^{s}	10.42 W
	λ_{CPU}^{s}	100%
	N_s	20

With N_{NB} the number of users per Node B.

For the wifi case we assume a WLAN access point at the user premises using an ADSL connection to connect to the access network. The code of conduct on energy consumption of broadband equipment [5] defines power level targets for the user premises equipment and power lever per connection targets for the access network equipment. This leads to a network power consumption per user of:

$$P^{n} = P_{0}^{WLAN} + P_{0}^{ADSL} \tag{9}$$

D. Cooling

Due to the concentration of heat dissipating equipment, considerable efforts are needed to cool data centers. This cooling infrastructure of course also consumes electrical power. Therefore not all electrical power consumed by the data center is used for the ICT equipment. This factor is denoted by the Power Usage Effectiveness (PUE) [6]:

$$PUE = \frac{P_{tot}^{dc}}{P_{tot}^{ICT}} \tag{10}$$

Since our model should cover multiple cases we will consider the PUE accounted for in the relevant parameters.

E. Total

Adding up all components leads to the total power consumption for both cases. For the UMTS case we get a total power consumption per user:

$$\begin{aligned} P^{tot} &= P_{0}^{c} + P_{act}^{c} f_{act} + \frac{1}{N_{NB}} P_{0}^{NB} \\ &+ \left(P_{0}^{s} + \alpha_{CPU}^{s} \lambda_{CPU}^{s}\right)\frac{1}{N_s} + \left(\alpha_{T}^{c} + \alpha_{NIC}^{s}\right) b \end{aligned} \tag{7}$$

For the wifi case this becomes:

$$\begin{aligned} P^{tot} &= P_{0}^{c} + P_{act}^{c} f_{act} + P_{0}^{WLAN} + P_{0}^{ADSL} \\ &+ \left(P_{0}^{s} + \alpha_{CPU}^{s} \lambda_{CPU}^{s}\right)\frac{1}{N_s} + \left(\alpha_{T}^{c} + \alpha_{NIC}^{s}\right) b \end{aligned} \tag{8}$$

III. EXPERIMENTAL RESULTS

We evaluate the power consumption in order to compare

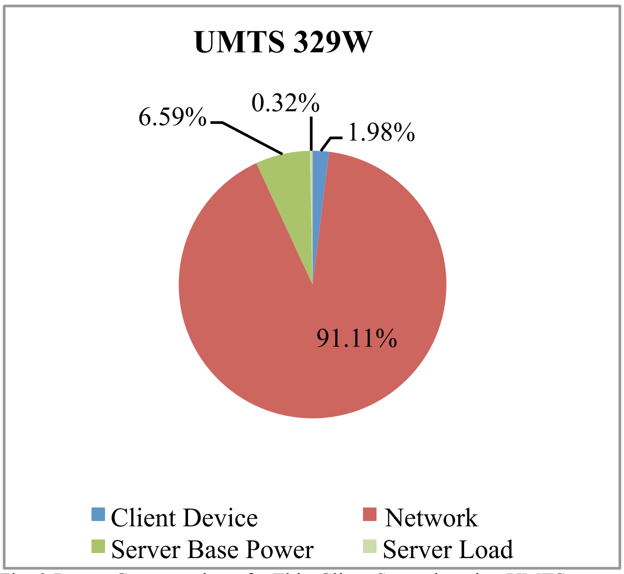


Fig. 2 Power Consumption of a Thin Client Scenario using UMTS

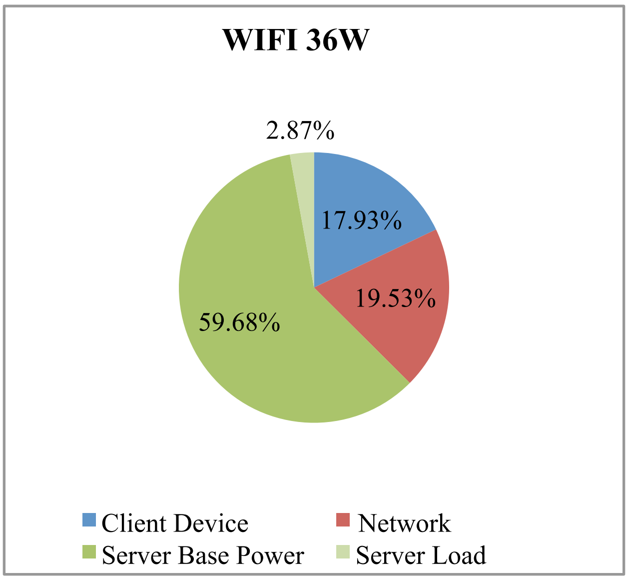
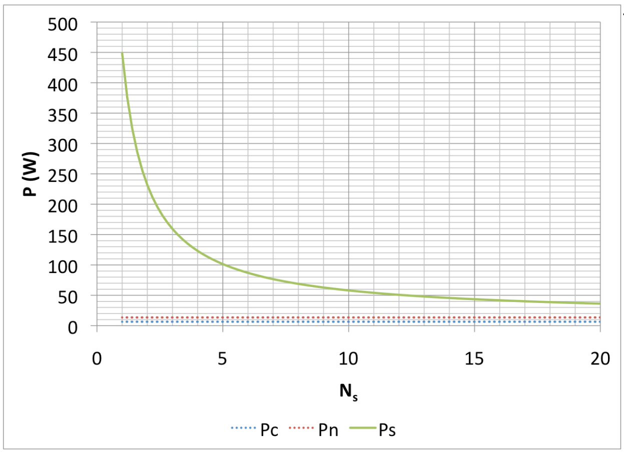
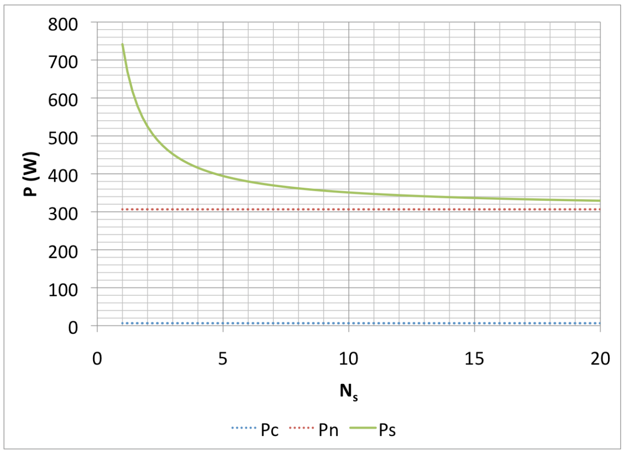


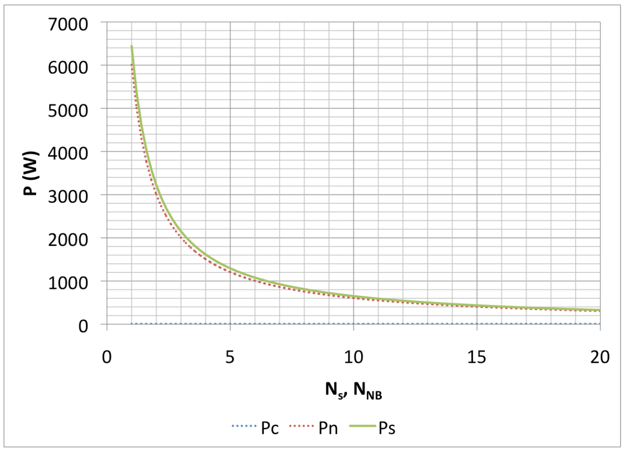
Fig. 3 Power consumption of a Thin Client Scenario using Wifi



(a) wifi



(b) UMTS, N_{NB}=20



(c) UMTS, variable N_{NB}

Fig. 4 Incremental chart of Power consumption of Thin Client Scenario with variable N_S

both cases. We measured the power consumption of a mobile device (HP iPAQ hx2490) and a server (AMD Opteron 2212).

In the client device the factor α_T^c appears to be negligible (order $\frac{\mu W}{Mbit/s}$). Moreover the network connection needs to be constantly online in order to transmit I/O signals. Therefore we will consider P^c being constant. On the server side we assume a PUE of 2, which is a common value. The considered applications are typical office applications such as text editors and spreadsheets. We assume λ_{CPU}^{app} to be 5% (note that on a regular desktop PC this would represent a CPU load of approximately 20%) [4]. The thin client protocol overhead ε is considered to be negligible. In order to maximally use the server resources we use a share ratio of $N_s = 20$. The consumed bandwidth varies between 0 and 5 Mb/s [4]. For the wifi case we based ourselves on [5]. For the Node B we assume an average power of 6kW and an average of 20 users. The used power values are summarized in Table I.

When we look at the power consumption in Fig. 2 and Fig. 3, it is clear that the wifi case is a lot less power consuming than the UMTS case. This is due to the power consumption in the UMTS case being heavily dominated by the network devices that consume more than 90% of the power. In the wifi case the network power consumption is very low.

The displayed analysis in the power consumption is based on the optimal condition where the servers are used at up to 100%. When the server share ratio N_s decreases, the power consumption obviously increases. In Fig. 4 we have displayed the power consumption in three cases.

In Fig 4 (a) we have displayed the wifi case. One can see that the power consumption is heavily dominated by the server power consumption. It is clear that for $N_s < 5$ the power consumption is significantly higher. But also for higher N_s the amount of extra power consumption is still considerable. With a varying number of connected users it will be important to assure that the number of users per server is kept as high as possible. This can be achieved by building a flexible server farm. In this server farm only the necessary number of servers is active and the rest is either switched of or in standby mode. Only when more users become online than the active servers can handle extra servers are activated.

In Fig. 4 (b) and Fig. 4 (c) we have analyzed the power consumption with variable users in the UMTS case. We have considered two subcases. In the first case the (optimal) number of users per Node B can be maintained. We assumed this number to be 20. In the second case the number of users per Node B degrades together with the number of users per server. It is clear that the considerations concerning the server power consumption are still valid. The network power consumption is however becoming more important. The number of users per Node B is however a factor that cannot be controlled contrary to the number of users per server.

IV. Conclusion

The thin client paradigm is considered as a solution for enabling mobile devices to run complex applications. In light of the current attention for energy efficiency it is important to review the power consumption of the thin client paradigm.

We created an analytical model to determine this power consumption. It is clear that the power consumption when implementing a wifi scenario is a lot lower than when implementing an UMTS scenario.

Some inefficiency factors can still impair the power consumption. Some of them, like the number of users per server are manageable. Others, like the number of users per Node B in the UMTS scenario are harder to manage.

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