# Remote Management of Mobile Devices with Broadband Forum's TR-069

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*Abstract* – **Remote device and network management can play an important role in realizing efficient and user-friendly deployment of fixed-mobile converged network services. TR-069 is currently the most popular remote-management protocol in the DSL world, but is not used in mobile networks. This paper investigates the applicability of TR-069 for remote device management of mobile devices. We installed a TR-069 client on a mobile phone, and measured the performance of the protocol in relation to the properties of the mobile data connection and the small footprint of the mobile device. The results confirm theoretical considerations derived from literature. The main conclusion is that TR-069 can be safely used for remote management of mobile devices, but requires a higher connection capacity of the remote management server due to the longer connection times in mobile networks.**

*Index terms* – **TR-069, remote management, personal networks, fixed-mobile convergence, integration of heterogeneous networks, end-to-end protocols.**

## I. Introduction

NOWADAYS, mobile devices are ubiquitous, and may take part in the formation of Personal Networks (PNs). A PN is a virtual, secured network by which an individual has seamless access to his own personal services, devices and content, irrespective of their physical location [1]. Simple examples of PNs are personal area networks, home networks, and in-car networks. A more advanced example is the virtual network that is created by maintaining a fully transparent connection between a personal area network (PAN) and a home network independent of their relative location, as depicted in Figure 1 [2]. These advanced PNs will often be heterogeneous in their technical composition, and demand many control and management actions to function properly. This is where protocols for automated control and remote management come into play. Control protocols are meant for real-time functions such as connection control, session control, service control, signaling, resource discovery, and resource management. Typical examples are Session Initiation Protocol (SIP) and Universal Plug and Play (UPnP). Management protocols, such as Simple Network Management Protocol (SNMP) typically deal with non-real-time management functions, such as fault-, configuration-, performance-, and security management [3].

Service providers are expected to offer new network and application services to many similar devices in a PN, irrespective of their access technology. Provisioning of these services requires proper configuration of all devices involved in a coherent way. Therefore, service providers prefer to use a single remote management system for the configuration of fixed as well as mobile devices to reduce operational costs. PNs are thus considered as a concrete example of added value that can be achieved by fixed-mobile convergence [4].

In both the mobile and the fixed broadband access world, remote management of personal devices is still subject of research and development. The Open Mobile Alliance (OMA) recently developed the OMA Device Management (OMA-DM) protocol [5] for mobile devices. Broadband Forum (formerly know as DSL Forum) has standardized the Customer Premises Equipment (CPE) Wide area network Management Protocol (CWMP, but often simply called TR-069 [6]) for remote management of devices in the home network.

At this moment, TR-069 is widely being deployed for CPE management, whereas ubiquitous deployment and use of OMA DM has been slow. In this paper we will therefore investigate whether TR-069 is appropriate for remote management of mobile devices, taking into account the data transport performance of the mobile data connection and the small footprint of mobile devices. In the following section TR-069 is introduced. Section III discusses the performance of TR-069 to be expected in mobile networks based on what is known in literature. Finally, in section IV and V we describe our test setup and the results of our performance measurements, respectively. The experiments are carried out on a General Packet Radio Service (GPRS) network, which is the data packet service with the lowest bit rate currently in use (also for fancy 3G phones with much manageable functionality), compared with newer technologies.

## II. TR-069

### A. Overview

TR-069 [6] is a Broadband Forum standard for remote management of Residential Gateways (RGs) or Broadband

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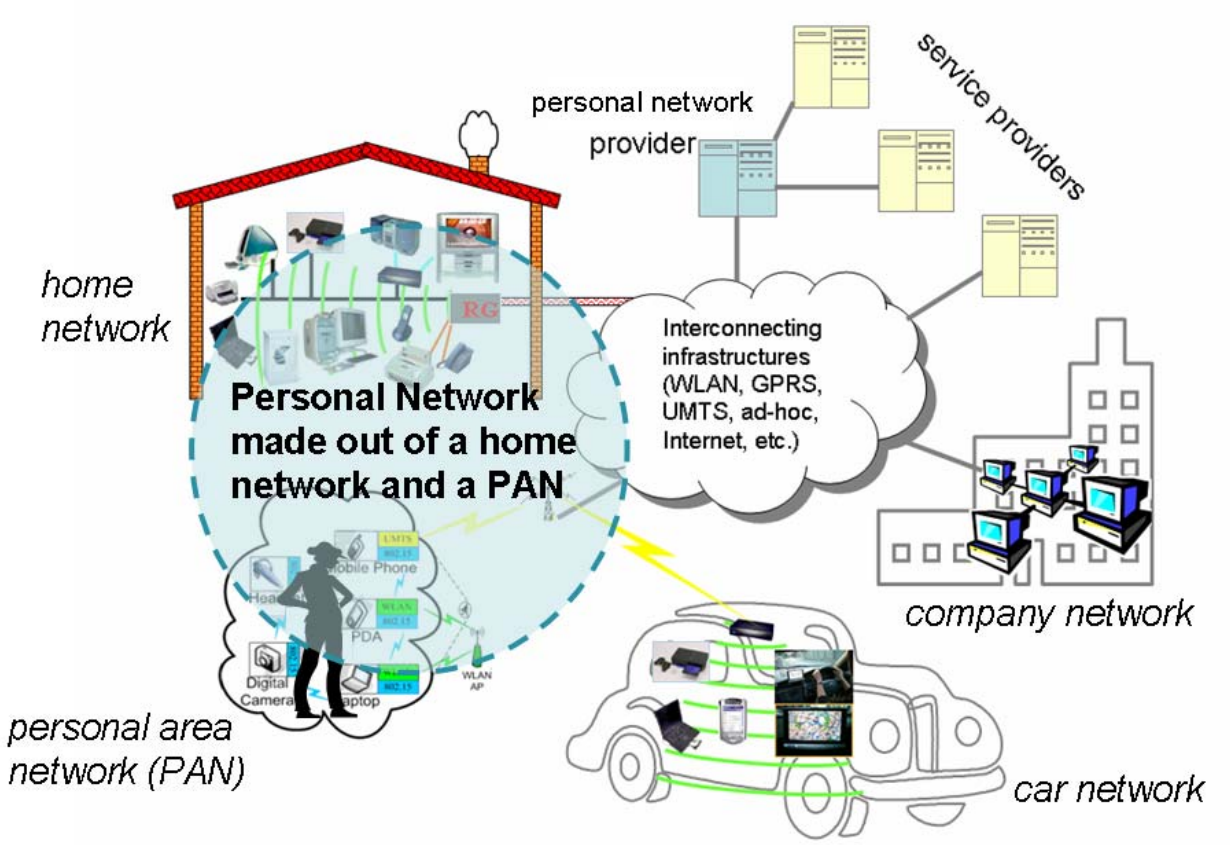


Figure 1. A PN is a personalized overlay over multiple network domains, here a PAN and a home network.

Network Terminators (B-NT), and other CPE. It focuses onconfiguration management, but also contains some performance and fault management functionality. It consists of a management architecture and the definition of CWMP. Figure 2 shows the architecture for the management of a B-NT and other CPE in the Local Area Network (LAN) by an Auto-Configuration Server (ACS), where the ACS and B-NT are assumed to be interconnected by a fixed broadband network.

CWMP is an Internet Protocol (IP)-based protocol and uses eXtended Markup Language (XML) for all messages. It runs over Transport Control Protocol (TCP) and uses Secure Sockets Layer (SSL) or Transport Layer Security (TLS) to provide transaction confidentiality and to allow various levels of authentication. The protocol is based on web services and uses Hypertext Transfer Protocol 1.1 (HTTP) and Simple Object Access Protocol 1.1 (SOAP). In SOAP messages, the

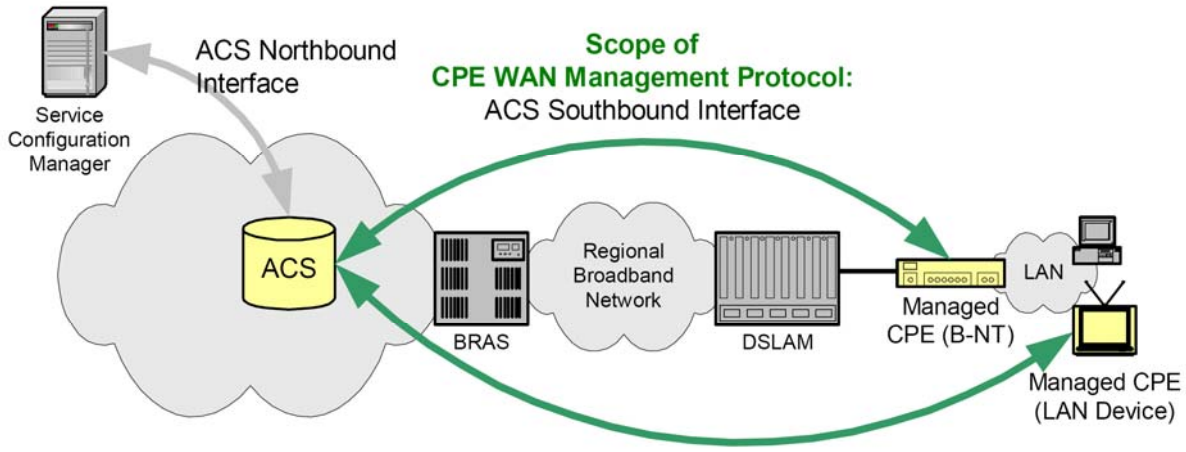


Figure 2. Positioning of CWMP in the Broadband Forum Auto-configuration Architecture [6]

TR-069-defined Remote Procedure Call (RPC) methods can be executed resulting in management actions.

The management sessions are always initiated by the CPE. The ACS can also request the CPE to setup a management session. For the initiation of a management session, the CPE uses a predetermined IP address of the ACS (locally preconfigured or received via Dynamic Host Configuration Protocol (DHCP). A connection with the ACS can be set up at the occurrence of a specific event, and/or periodically. The CPE must present any preconfigured information to the ACS, e.g. the first time the CPE establishes a connection to the access network, on power-up or reset, and once every periodically configured time interval.

The first message the CPE sends to the ACS is an information request that informs the ACS about CPE information (identification, manufacturer, serial number and the most important parameters). Then, the CPE may send other messages to the ACS, and the ACS can send commands to the CPE to be executed. The CPE closes the session when both CPE and ACS no longer have requests and all responses are given.

The RPC methods are defined for the CPE as well as the ACS. Baseline methods of CWMP concern description, control and eventing. CPE and ACS can 'get' information about available methods and parameters with description methods. The ACS can control the CPE with methods that can 'get' and 'set' parameter values. New instances in the data model can be built and deleted with a method for respectively adding or deleting objects. Other control methods are available for rebooting and file downloading. An eventing method is the information request that the CPE sends to the ACS when it initiates a session. That request informs the ACS about the reason for the session and gives, when possible, a list of modified parameters with their new values. For consistency reasons, a CPE can only contact one ACS at a time.

Companion standards of TR-069 give data models for different device types, e.g. Internet Gateway Device [7]. A data model consists of a tree-like structure with optional and required parameters and the option to define vendor-specific parameters in a standardized way. Parameters can be 'read-only', 'read-write', or 'write-only'. It is also possible to define an array of parameters or an array of structures.

An important standard for the remote management of other CPE than RGs, like those used in a PN, is TR-106 [7]. In this document, the generic data model for any device that conforms to TR-069 (and thus can be managed by using CWMP) is specified. By conforming to this standard, it is possible for manufacturers to build an ACS that can handle all kinds of different devices, at least to some extend, because all the generic information is always available in a standardized way.

Advantages of CWMP over SNMP are the facts that the data models are standardized and that the protocol includes proper security methods. Furthermore, better scalability and cost reduction results can be achieved, due to the session initiation reserved to the CPE and the short session times allowing more CPE simultaneously managed by the ACS.

### *B. Network performance requirements*

A typical management session in CWMP looks like the subsequent actions for a control method as depicted in Figure 3. A management session is always initiated by the client by issuing an **Inform** message. The client identifies itself in this message, which is acknowledged by the server with an **InformResponse** message. After this handshake, the server can request the value of one or more parameters with a **GetParameterValue** message or set one or more parameters with a **SetParameterValue** message. Both messages are acknowledged, with a **SetParameterResponse** or **GetParameterResponse**. In the latter, also the values of the parameters are included. The management session is finished by closing the TCP/IP connection.

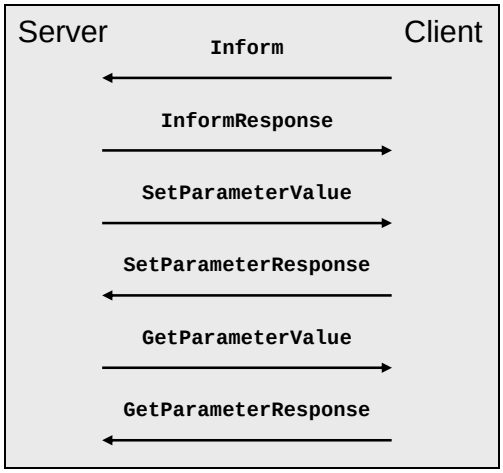


Figure 3. Example of a CWMP management session, starting at the top.

The transaction time for remote management actions depends on many factors, such as:

- the amount of data to be sent and received including the protocol overhead,
- the bandwidth of the management data channel,
- the device performance of the mobile device and the remote management server,
- and the number of devices to be simultaneously managed by the remote management server.

In our experience, a realistic value for the size of a configuration file is 0.1 MB, assuming a Voice-over-IP enabled RG needing 2000 parameter lines of 50 one-byte characters. Encryption and added Access List Control data adds about 20% extra overhead. Uploading to a CPE should take 60 seconds at most, resulting in a minimal required bit rate of 15 kbps. Assuming a remote management server with a capacity of 1000 simultaneous sessions, this results in 1.4 million uploads per 24 hours.

TR-069 is not sensitive for delay and jitter in the data transport. However, there is usually a timeout defined in the TR-069 client and in the remote management server for waiting on responses.

## III. GPRS PERFORMANCE

### A. GPRS compared to other technologies

We investigated if CWMP is appropriate and, in particular, sufficiently robust for running over mobile channels and on mobile devices. Under the condition that the TCP layer shows a good performance, we can expect a good operation of CWMP running over any TCP/IP connection. In mobile applications, TCP/IP runs over a mobile channel that is suited for connection orientated data transport. Mobile technologies that are currently available are, for instance, GPRS, Enhanced Data rates for GSM Evolution (EDGE), Universal Mobile Telecommunications System (UMTS) and High-Speed Downlink Packet Access (HSDPA). In this paper we study the performance of CWMP over GPRS because GPRS is most widely deployed (also as backup connectivity for other technologies), and GPRS is expected to offer the lowest technical performance. When GPRS performance is satisfactory it can be expected that EDGE, UMTS and HSDPA will perform even better. In the following sections, the performance on data rate, delay, jitter, and quality of the GPRS connection are discussed.

### B. Data rate

A comprehensive description of operation and service characteristics of GPRS can be found in [9]. The performance of GPRS is investigated in [10]-[12]. The data rate of GPRS depends on the number of available Packet Data CHannels (PDCH) and the coding scheme (see Table I) which depends on the quality of the connection. When the quality of the connection decreases, the system automatically adapts to a coding scheme (CS) with lower coding rate, and the data rate will decrease.

The use of coding schemes varies from CS-4 in the neighborhood of the Base Transceiver Station (BTS) until CS-1 further away. CS-1 is the most robust coding scheme and applies more error correction. The number of PDCHs to be used depends on the GPRS multi-slot class applied for a specific GPRS service. The number of available uplinks, downlinks and allowed active slots defines the multi-slot class. The minimal GPRS implementation uses Multi-slot Class 1, with 1 downlink, 1 uplink and 2 active slots. This results in send and receive speeds of only 8-12 kbps, which are too slow for the support of CWMP. Multi-slot Class 12 has 4 downlinks, 4 uplinks and 5 active slots resulting in speeds of up to 48 kbps, which is sufficient for remote management.

TABLE I. GPRS CODING SCHEMES [11] (FOR ONE PDCH OR SLOT)

| Coding Scheme | Code Rate | Payload Bits per RLC Block | Data Rate |
|---|---|---|---|
| CS-1 | 1/2 | 160 | 8.0 kbps |
| CS-2 | ~2/3 | 240 | 12.0 kbps |
| CS-3 | ~3/4 | 288 | 14.4 kbps |
| CS-4 | 1 | 400 | 20.0 kbps |

### C. Delay and jitter

Other quality performance metrics are delay and jitter. In [9] and [14] requirements for these Quality of Service (QoS) attributes are presented for different sizes of data packets. Table II presents the allowed delays for different sizes of data packets in four QoS classes. In QoS Class 1 a mean delay of at most 0.5 s with a 95% deviation of 1.5 s is allowed for 128 byte packets. The delay increases significantly for larger packet size and QoS class. We therefore conclude that delay and jitter may vary greatly in GPRS networks. However, we do not expect that these delays will disturb the TR-069 data transport because of the properties of TCP and the limited real-time requirements of the remote management application. Handovers add less than a second to these delays and the chance that they occur during a management action is very small.

TABLE II. QOS REQUIREMENTS FOR DIFFERENT SIZE OF DATA PACKETS IN GPRS [9],[14]

| Size / Class | 128 octets | | 1024 octets | |
|---|---|---|---|---|
| | ***Mean Delay*** | ***95%*** | ***Mean delay*** | ***95%*** |
| 1 (predictive) | 0.5 s | 1.5 s | 2 s | 7 s |
| 2 (predictive) | 5 s | 25 s | 15 s | 75 s |
| 3 (predictive) | 50 s | 250 s | 75 s | 375 s |
| 4 (best effort) | Not specified | | | |

### D. Bit Error Rate and connection quality

Another aspect of performance is the bit error rate. Error rates in GPRS due to lost, corrupt, duplicate and out-of-sequence data are specified to be less than $10^{-9}$ due to error detection and correction procedures performed by the protocols below the IP layer [9],[14]. These error rates can be easily handled by the higher layer protocols and are therefore acceptable for the TR-069 application.

The connection quality is about the proper operation of the connection in situations of handover, roaming, abruptly breaking and restoration. In mobile systems, the occurrence of a handover does not require to setup a new TCP/IP connection. During handover, the TCP/IP session is frozen and will continue when the user terminal is connected to the new cell. In general, a TCP connection will not be disconnected unless a TCP timeout is passed.

In the case of roaming to another provider – e.g. when one passes the country border – the session will be broken and a new IP connection and TCP session must be established. In this case, a CWMP management session is terminated prematurely. CWMP includes mechanisms to cope with this, e.g. a retry of the session when a new connection is available. From the specifications, it is not evident whether these mechanisms guarantee correct management of the CPE and consistency of the data in the CPE and ACS in all cases. However, it is not expected that this will cause significant issues in practice, because the probability of an abrupt

termination of a management session due to a network provider handover is small. However, similar issues could arise when turning off the mobile device, which is an event that occurs much more frequently. Therefore, this issue needs further investigation before CWMP is deployed over mobile channels in large scale.

### *E. Hypothesis*

From the previous sections, we expect the CWMP protocol to run properly over GPRS (and therefore also over HSDPA or UMTS) provided that the GPRS network is reasonably dimensioned and the mobile devices are not switched off too often. We have verified this hypothesis by implementing and testing CWMP over a GPRS link. The results of these tests are presented in section V. With this implementation we have also tested whether current mobile telephones have sufficient resources to run a management client based on CWMP.

## IV. Test Setup

For comparison purposes we have designed a test set up (see Figure 4) consisting of a mobile chain (a) and a fixed chain (b). The mobile chain connects a mobile device via a GPRS network and a corporate network to a LAN with an ACS. The fixed chain (b) connects a personal computer (PC) to a LAN with an ACS. Both chains use the ACS for managing the mobile device respectively the PC.

In both test setups, the ACS is a PC provided with Linux and Dimark's DPS Auto Configuration Server version 1.0 (unreleased) [15]. DPS is able to act as middleware between the operator's Operations Support System (OSS) and the devices to be managed. DPS has a web interface that provides a list of devices and manageable TR-069 parameters. DPS uses a HyperSonic SQL DataBase (HSQLDB) and an Apache/Tomcat webserver with Apache Axis as SOAP implementation.

The mobile device in test setup (a) is a QTopia GreenPhone [16]. It runs Linux and its capabilities (Marvell PXA270 312 MHz application processor, 64MB RAM) are comparable with currently available mobile phones. As a TR-069 client we used Dimark's TR-069 Client Implementation version 2.2.4, programmed in C. We recompiled the Dimark TR-069 Client for the GreenPhone's Advanced Reduced Machine instruction set. In test setup (b) we used the same Dimark TR-069 Client but now running on a PC.

For measuring time, CPU usage, and memory usage, we employed well-known Linux OS functions. For measuring data transport time we used: Ethereal Protocol Analyzer (currently WireShark [17]). For tracking HTTP traffic and SOAP/XML messages we used a TCP monitor that is integrated in the Dimark ACS. Multi-slot class, coding scheme, delay and jitter were not registered.

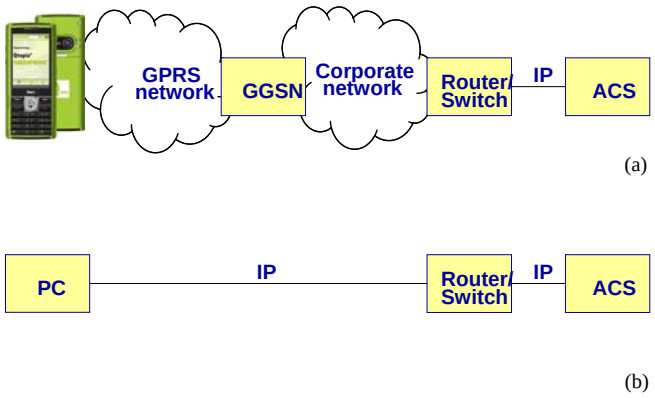


Figure 4. Test set-up for measuring the performance of CWMP over (a) a GPRS and (b) a fixed connection.

## V. Performance Test Results

### *A. Bandwidth of the data transport when sending parameters*

The question is how much time a short provisioning action takes when sending one parameter over GPRS, as compared with sending this parameter over an Ethernet-based LAN. To answer this, we measured the time needed for session initiation and data transport between the ACS server and the TR-069 client over a LAN channel and over a GPRS channel and compared the results. In the TR-069 client we defined a new parameter. The value of this parameter is a string of 1952 characters that corresponds with approximate 2KB. In the ACS we performed a SET followed by a GET command and measured the time that the different protocol steps as depicted in Figure 3 take. By using a protocol analyzer we were able to inspect the sent and received data with their time stamps. The server received 6410 bytes in 10 TCP packets and the client received 2811 bytes in 20 TCP packets. The results of the time measurements are presented in Table III. The connection setup time is the time from the first IP packet being sent untill the first packet containing the TR-069 Inform message. The data exchange time is the time between the packet with the Inform message and the last IP packet being transmitted.

From Table III it can be concluded that the total time of a remote management data exchange over GPRS takes 13 s within the context of our set-up. That is more than 10 times longer than in the fixed network. The mean remote management date rate for GPRS is found to be 5 kbps.

TABLE III. Measured times for setting and getting one parameter for a mobile client and a LAN client.

| | **Mobile CWMP client** | **Fixed CWMP client** |
|---|---|---|
| **Connection setup time** | 3 s | 0.1 s |
| **Data exchange time** | 10 s | 1 s |
| **Mean data rate** | 5 kbps | 61 kbps |

### B. *Bandwidth of the data transport when sending files*

Another matter is how much time a provisioning action takes when sending complete configuration files over GPRS. For that, we measured the time needed for session initiation and data transport between the ACS server and the CWMP client over a GPRS channel. We did not perform comparing measurements over a fixed connection because sending files in a 100 Mbps LAN takes negligible time. In practice, the initial configuration (provisioning) of the phone is performed by sending configuration files with many parameters included. The option of file transfer was not available in our evaluation versions of the CWMP client and the ACS. To perform file transfer nevertheless, we used the command line software of CURL [18] and registered the transfer time with the function **time** of the Linux OS. Figure 5 shows the measured mean data rate over GPRS as a function of the CWMP file size. The measurement was repeated four times, and the figure shows the average values of the individual measurements and the standard deviation. The line is a fit through the data, assuming a constant connection setup time ($t_0$) and a constant *instantaneous* data rate ($v$):

$$R = S /( t_0 + S * v) \qquad (1)$$

with $R$ the mean data rate and $S$ the file size. From the fit, we found $t_0$ = 3.9 ± 0.4 s and $v$ = 38.1 ± 0.3 kbps. The results indicate that the data can indeed be understood by assuming a constant connection setup time and a constant instantaneous data rate. This indicates that there is no systematic dependency between the data rate and the file size.

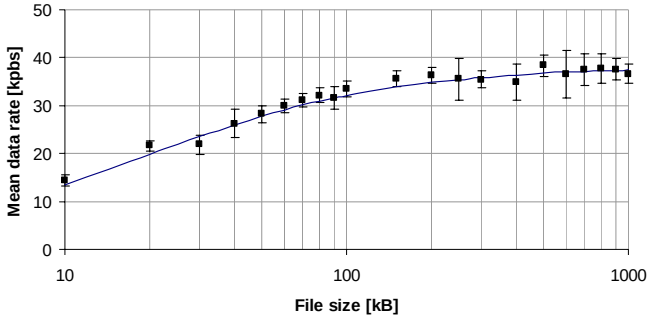


Figure 5 Measured mean date rate when sending data files over a GPRS connection (a) as a function of file size.

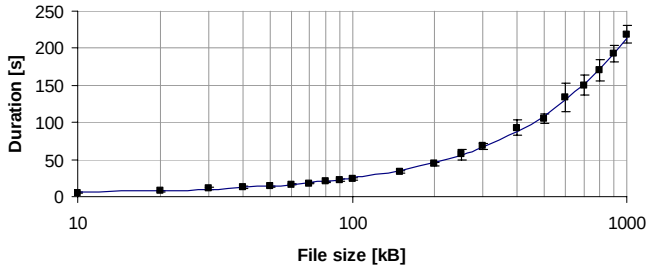


Figure 6 Measured duration when sending data files over a GPRS connection (a) for different file size.

Figure 6 shows the measured duration of sending CWMP data files over GPRS for different file sizes, based on the same data set as used in Figure 5. For files smaller than 250 kB, the the transfer time stays below 60 s, which was considered as being a reasonable maximum in Section II. Since configuration files are typically 100 kB, we can conclude that GPRS is fast enough for supporting CWMP.

### C. *Computer memory and CPU usage*

One should also consider the memory usage when running the TR-069 client on the smart phone. The size of the TR-069 client executable is found to be 2.5 MB. Here we note that the size of the executable was not optimized. We tested the memory usage of operation by using the Linux OS functions **top** or **ps**. The memory usage must be registered at the moment of switching the GPRS connection ON and the ACS connection OPEN. In Table IV the results are presented. The memory usage of the CWMP client via GPRS in connection with an ACS amounts to 1400 kB for GPRS ON and ACS connection OPEN. Looking at the fast growth of available memory in smart phones, we therefore do not expect bottlenecks regarding memory usage.

TABLE IV. MEMORY USAGE OF GREENPHONE WHEN STARTING UP GPRS AND ACS CONNECTION.

| Connection | State | Memory usage |
|---|---|---|
| GPRS | OFF | 992 kB |
| GPRS | ON | 1056 kB |
| ACS | OPEN | 1396 kB |
| ACS | CLOSED | 1396 kB |

Also the processor speed of the GreenPhone could be a bottleneck when transporting TR-069 data over GPRS. We found the CPU usage during the file transfer of 100 kB files to be 30 ms. That is only 1% of the total time needed for processing the data. The CPU usage of the GreenPhone will therefore not be a bottleneck for applying CWMP over GPRS.

## VI. CONCLUSIONS

This paper investigates if the Broadband Forum's TR-069 CPE WAN Management Protocol can be used for remote management of mobile devices. For delivering services to highly heterogeneous Personal Networks, the use of a single management protocol for fixed as well as mobile private networks can be attractive from a scalability and a cost point of view.

Theoretical considerations and experimental verification of the performance of TR-069 as a function of the various properties of the mobile connection and given the small mobile device footprints did not reveal insurmountable problems and prove that the CWMP protocol can be used safely for remote management of mobile devices.

The low bandwidth of GPRS is no limitation for the operation of CWMP but can result in longer connection times compared with fixed line technologies. Longer connection

times will have impact on the remote management server capacity for concurrently connected users.

For critical situations, the TR-069 performance may be improved by data compression of the XML files, leading to a reduction of the file size with a factor of up to 20. The Broadband Forum could consider the standardization of a specific compression algorithm, because the parameter name always contains the whole tree name.

Further investigation is needed on the effect of interrupted management sessions by e.g. power failure, bad reception and hard handovers. Also the performance of other provisioning processes and bootstrap actions that are needed should be studied. Finally, for a good comparison, the applicability of OMA-DM over fixed networks should be studied too.

## ACKNOWLEDGMENTS

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