Monitoring Real World Usage of Network Connected Products in the Home: Experiences from the UK and Opportunities for Replication in the US and Other Regions

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ABSTRACT

Standards and labeling programs ensure products are designed to meet prescribed energy efficiency performance requirements; including the need to power down when not in active use. However at present, the potential energy savings attributed to the 'standby' requirement are not being met. Many household electronics are now network-connected and are rarely powered down to ensure constant monitoring of data traffic through the device to receive updates and respond to network triggers.

Examining the way in which consumers use these products in the "real world" environment can provide insight to the level and type of network traffic in devices in the home at different times of day. Where there are regular periods of negligible network traffic common to the majority of users, savings can be achieved by switching devices into a lower energy consuming mode during these periods.

If network equipment devices are powered down for 6 hours in every 24 hour period, savings of up to 25% of the total product energy consumption can be realized. Technologies exist that enable network devices to reduce power during times of low utilization, so considerable energy can be saved without comprising functionality for the user.

This paper will propose recommendations to policy makers based on a real time data collection exercise carried out in the UK, to analyze the "real world usage" of network connected devices. The paper will also map out how to replicate the project approach and methodology in the US and other regions, to determine whether similar opportunities exist in other areas.

Introduction

The majority of domestic network installations have at their heart a home gateway or router/modem which connects all devices within the home to the Internet or World Wide Web. The number of devices in the home or office that operate on a network is growing rapidly, with estimates suggesting there will be 15 billion connected devices, including tablets, mobile phones, connected appliances and other smart machines, by 2015 (Cisco, 2011). There are estimated to be around 19 million Internet access devices, or residential home gateways, in use in the UK operating on an "always on" basis, even though they are likely inactive a majority of the time (Defra 2012, 552-553). If usage needs for these products could be changed to "always available", then it seems likely that significant energy savings could be made. Although many of Internet Service Providers (ISPs) incorporate lower power modes to reduce energy consumption when the device is not providing a core function, further opportunities to save energy may exist. By monitoring data/traffic flow through these devices, insight can be gained into:

- Types of products making “data calls” on the network;
- Duty cycles of products (and by extension, the home gateway); and
- Opportunities for improved energy efficiency of network devices.

The Super-efficient Equipment and Appliance Deployment (SEAD)[1] Initiative’s collaboration on network standby identified an opportunity to evaluate how network-connected devices are used in the home, and as such, whether there is scope to improve the energy efficiency of these products. The project was strongly supported by the UK’s Department for Environment, Food and Rural Affairs (Defra), following their involvement in research on an earlier project entitled “Powering the Nation”, which monitored electrical power demand and energy consumption by products in UK homes.[2]

The key aim of this SEAD project was therefore to provide an insight to the way a representative selection of volunteer broadband customers use their network to enhance the clarity of the information available regarding the way in which networks are used in the real world domestic environment. Other SEAD participating governments expressed an interest in both the outcomes of the project as well as the study methodology, as there is an uncertainty whether results from the UK can be representative of households in other European Member States and on other continents where usage trends may be different.

This paper presents the project methodology for the SEAD Real World Usage Study of Domestic Networks, incorporating lessons learned from the UK experience. It then summarizes results of the data analysis and identifies opportunities for energy savings arising from these results. Finally, it proposes recommendations and opportunities for the US and other regions looking to replicate the project and compare results with the UK analysis.

Project Methodology

The initial scope of this SEAD project sought to recruit one hundred volunteer households to participate in a micro-data collection exercise, whereby the real-time network traffic in each home would be monitored and assessed by the project team in collaboration with key internet service providers (ISPs). The volunteer household recruitment exercise took place in parallel to the discussions with ISPs, before a final process for collecting the data had been agreed with the ISPs. For internal reasons, potentially due to the intrusive nature of the individual household monitoring exercise and confidentiality concerns, some of the ISPs involved in the project chose to adopt a different approach from the project brief, collecting macro-level data. This substantially reduced the number of individual households participating in the study, which was an unintended consequence of the project methodology. For this reason,

[1] The SEAD initiative of the Clean Energy Ministerial is comprised of government representatives from 16 economies, and is supported by both CLASP and the Lawrence Berkeley National Laboratory. See www.superefficient.org for more details.

[2] The report presents results of a survey of 251 UK households that was undertaken to monitor the electrical power demand and energy consumption over the period May 2010 to July 2011. The project was funded by Defra, the Department of Energy & Climate Change and the Energy Saving Trust.

this section sets out a project methodology which incorporates key lessons learned from the UK experience, so that similar issues can be avoided in future projects.

Initiate Discussions with the Participating Internet Service Providers

First and foremost, the project team, with support from Defra, engaged in discussions with the ISPs to introduce them to both the SEAD initiative and to the project concept.

The project team approached the four largest ISP companies in the UK[3], of which three expressed an interest in the research. Representatives from each ISP were invited to Defra's offices in London to discuss the project, the reasoning behind it, and its goals, as well as what the ISPs potential involvement would be. Defra's association to the project was integral towards securing the support of the ISPs: it corroborated the consultant's pitch by reducing any skepticism towards the intent of the in-home monitoring exercise; it highlighted the energy efficiency concerns stemming from increasingly network connected products; and the ISPs were introduced to the SEAD initiative[4] and made aware of the impacts this pilot study could have at the international level.

After multiple discussions, all three ISPs agreed to participate in and support the research. The project team was asked to sign non-disclosure agreements with each ISP and more detailed discussions were initiated with the nominated technical expert within each company.

This proved to be a lengthy endeavor with some unanticipated delays: due to the nature of the request, contacts from the technical, environmental, corporate affairs and legal departments within each organization had to be consulted, and the request was made during the summer months, when many staff members were on leave.[5]

Choice of Monitoring Methodology

Choosing where to monitor the network traffic in households was a key aspect of the project. The two most valuable data collection location sites were at the home gateway point, as well as at the exchange point.

In home monitoring. In the case of in-home monitoring, a dedicated piece of equipment would need to be installed in each customer's home. To avoid disruption to the customer's internet service, the ISP's home equipment would need to remain in place. The project team considered the possibility of installing equipment alongside the existing home gateways, but this would significantly drive up the cost of the project once equipment, installation and labor costs were considered. The pieces of equipment installed would need to record all information collected during installation, and then upload this information periodically which would increase network traffic in the home, thereby distorting the data collection results.

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[3] These companies cover some 19 million broadband customers, representing the vast majority of the market.
[4] At the project initiation phase, the SEAD initiative was relatively nascent and mainly promoted to governments. Manufacturers were aware of the initiative, however the initiative was not geared towards other stakeholders such as those in the telecommunications field.
[5] The request was made prior to the London 2012 Summer Olympics, when some of London shut down and staff members were encouraged to work remotely and avoid hosting London-based meetings.

Monitoring at the exchange or the ISP's network location. Collecting data at the telephone exchange was considered a more efficient method for the monitoring process. In this case, a single piece of equipment can examine a number of different customer locations, without the need for home visits. This not only reduces the inconvenience to the ISP customers, it also significantly reduces the project costs. Data can be collected at regular intervals and uploaded to a secure location, to be shared with the project team. There is no need to install equipment in the ISP network,[6] as they already have the equipment needed to monitor data traffic. While the equipment is not generally used for this type of activity, it was capable of providing the type of data necessary for the project research. Once the ISPs agreed to assist with the research, they had to agree to link their monitoring equipment to a single location on their network to gather specific, regional or national data for an extended period of time, as defined by the project brief.[7]

In agreement with the three different ISPs, the project team opted to use the latter approach to collect the necessary information for the project. In each case, the network monitoring equipment deployed enabled Deep Packet Inspection (DPI)[8] of the data from selected customers, however exact details of equipment and monitoring software used remain confidential to each ISP.

The Data Collection Process

The initial project scope called for a micro-approach to the data collection process, with in-house monitoring of data traffic. In order to move the project along, in parallel to the ongoing discussions with the ISPs, the project team initiated the market research phase of the project to recruit the required number of household volunteers (100 participating households). As agreements with ISPs had not been fully finalized, volunteer households were recruited that did not end up participating in the project. For internal reasons, two of the three ISPs chose to monitor a larger section of their customer base, providing macro-data at both the network and regional level. One ISP agreed to monitor the data as defined in the project brief, at the individual level. The micro-data collection process was therefore cut from 100 to 14 participants,[9] despite having established a successful market research methodology for the project.

Market research and recruitment for micro-data collection exercise. The project team partnered with Ipsos-MORI[10] to carry out the recruitment phase of the research study.

Using its Online Access Panel of around 240,000 households in the UK, the market research organization extensively profiled these members to identify target respondents with

[6] Nor would they agree to doing so.
[7] Usually this type of monitoring equipment is used for engineering purposes at particular exchanges. It is used to fix problems on the network, and once the issue has been resolved the equipment is moved onto the next location.
[8] Deep Packet Inspection (DPI) is a networking technology that ISPs use to monitor customers' data traffic, mediate its speed, and improve network security. This enables ISPs to identify what applications are generating data traffic.
[9] Only 14 households were using the service of that particular ISP.
[10] See http://www.ipsos-mori.com - Ipsos MORI conducts surveys for a wide range of major organizations as well as other market research agencies. They partnered with Intertek to carry out Defra's Powering the Nation study.

network-enabled devices to participate in a questionnaire for the project. A sample of 19,600 panelists, reflecting the UK online population profile, was selected to participate in an online survey which was prepared jointly by Ipsos-MORI and Intertek.

These panelists were incentivized to respond to the questionnaire, with a reward through the Ipsos-MORI points system[11]. In addition, respondents were told they would receive an Amazon voucher worth £8.64 if they were chosen to participate in the study. The questionnaire took on average around 15 minutes to complete and outlined details of the study and how it would work, including how network traffic would be shared with the project team. It also asked for information on the household, including which ISP they used, the length of time they have had internet in the home, the number of people in the household, whether they would be away for an extended period of time throughout the duration of the study, and details of the make, model and quantity of network-connected devices in their home. This information would help the project team determine from which devices specific data traffic is being sent. Respondents were also provided with information on the data collection process, as well as confidentiality assurance regarding their internet usage.[12]

Under the original project scope, the aim was to recruit at least 100 households. Ipsos-MORI therefore over-recruited 158 panelists to allow for potential drop outs throughout the project. Once the recruits were identified, an encrypted Excel data file of respondents was transferred to Intertek through a secure password-protected file sharing platform. A secure exchange of information is vital, as the data includes personal details along with demographic information. These respondents were then sent full details of the study, along with a consent form for them to sign and return to the project team.[13] Throughout the duration of the study, a helpline was available to participants in the event they had any questions or concerns regarding access to their network data traffic.

Ultimately, only respondents using services provided by the one ISP that agreed to provide individual household level data were selected to participate in the project, which greatly reduced insight at the micro-level, using the data collection methodology set out in the original project brief.

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[11] Ipsos-MORI respondents receive points that can be exchanged for retail vouchers.

[12] The questionnaire template and background materials are available for re-use by other organizations willing to carry out a similar study. These materials are available as an appendix in the original report.

[13] Templates are available within the appendix of the original report.

Macro-level data collection exercise. The two ISPs that decided not to provide individual household data agreed instead to provide data at a macro-level. One ISP agreed to provide a view of a larger number of households at regional level from around 6000 households. The other agreed to share a snapshot of their whole network usage over a 7 day period. Whilst this macro-level approach provided a much broader view of detailed UK household network traffic with greater statistical relevance, it removed the ability to examine and understand which equipment was used in each household.

Nature of Data to be Collected

The first challenge for the project team was to assess the data range provided by the three ISPs to determine how to carry out the most informative analysis. The unanticipated consequence of having three different levels of data, with a mix of optical fiber and twisted pair ADSL connection,[14] enabled the project team to adopt both the macro and micro view of domestic network activity using: 1) a top level approach with one set of data using a major part of the ISP network; 2) a more detailed approach with another data set using a single region; and 3) a very detailed approach using a small number of individual customers.

With the support of each ISP, information regarding the flow of data on the local area network (LAN) to and from the internet could be collected, without having to read the message contents of each data packet being transmitted. This limited, but sufficient, information would consist of volume and type of data packet transmitted within specified time internals to be agreed with the ISP. The monitoring was to take place over a minimum two-week period to allow for data analysis by time and by day, in order to identify data traffic patterns. In practice, the detailed analysis covered a period longer than two weeks.

Using DPI, the project team was able to examine the content of each data packet to establish its nature. The depth of resolution of the data was initially very detailed and could, for example, distinguish which type of streaming service the customer was using. The team therefore restricted the depth of resolution to identify the type of data only, so that this information could be characterized by category. This was clarified with both the ISP and the customers to ensure there were no data privacy issues. The following data types were collected for the study, as these are considered to make up almost the entirety of the network traffic in the UK:

- P2P applications
- Instant messaging
- Streaming applications
- VoIP
- File Systems
- Mail
- Web applications
- Network operation
- Terminals
- Database transactions
- Security
- Legacy protocols
- Games

[14] In the UK, the term fiber refers to both "fiber to the home" and "fiber to the cabinet". In some cases, the final connection from the cabinet is completed via high performance coaxial cable.

Another issue concerned security of the data collected. The ISPs sent through the most sensitive data, including non-aggregated data, in encrypted containers via a secure file transfer protocol (FTP) site with a limited time slot for download before the files were deleted. The required passwords were communicated securely and independently of any other information. Data was stored on secure servers and the analysis was carried out on a workstation with fully encrypted hard-drives. The customer data files were provided in a simple text format and omitted any details that could identify the customer directly. Each individual file covered a period of 24 hours. The data collected from each ISP is set out in Table 1 below.

Table 1. Data received from each ISP

ISP	Number of subscribers monitored	Duration of monitoring analysed	Data intervals	Detail
1	Entire data network (millions of subscribers)	7 days	30 minutes	By average bandwidth used
2	6000 subscribers	32 days	1 hour	By key protocol (top 4 identified)
3	14 subscribers	45 days selected from the larger total available	5 minutes	By protocol – information provided in highest detail

Source: SEAD Report, 2014.

Analysis of the Data

The project team received considerable and very helpful support from the ISPs for the data analysis phase of the project.

Two of the ISPs presented their data in spreadsheet format: one of these contained a pivot chart displaying key findings, while the other included analysis prepared by the ISP. The third ISP shared Character Separated Values (CSV) text files for each customer for each 24 hour period for up to 60 days. The collaboration with ISPs was incredibly valuable and encouraged some internal evaluation of the data, which may help raise awareness of wasted network bandwidth within the ISPs.

Whilst the data received in spreadsheets could be easily analyzed, the volume of data contained in the text files was incredibly large. The project team prepared programs and subroutines, using Visual Basic, to select and handle extraction of the data from around 1000 files to combine it into summary spreadsheets for a contiguous 45 day period. Visual Basic was not the only method that could be used to do this, but was found to be the most convenient given the format of the data presented. The subsequent analysis considered:

- The total usage of the network connection by time of day;
- Potential differences between weekdays and weekends;
- Key protocols by bandwidth used;
- Correlations between the network availability of customers' equipment and the type and volume of bandwidth used;
- Other aspects which emerged from graphical representations of the data; and
- The correlation between the macro and micro views of the data.

Summary of Data Analysis Results

The three-tiered data collection analysis enabled the project team to carry out a comparison of the different results, which proved that the small number of individual households monitored could serve as a representative sample of the UK's network traffic patterns.

Typical Network Usage

Network level analysis. Data from all subscribers on the specific network showed that aggregate network traffic varies by time of day. Figure 1 below shows the number of subscribers on an entire network whose usage exceeds a specific threshold measured in kilobits per second (kbps), measured at 30 minute intervals (4kbps, 8kbps, 16kbps etc). These results show decreased network activity over night time, as well as increased data traffic throughout the day that reaches a peak in the evenings. Night time traffic is fairly regular throughout the whole week, whereas day time traffic increases on the weekends.

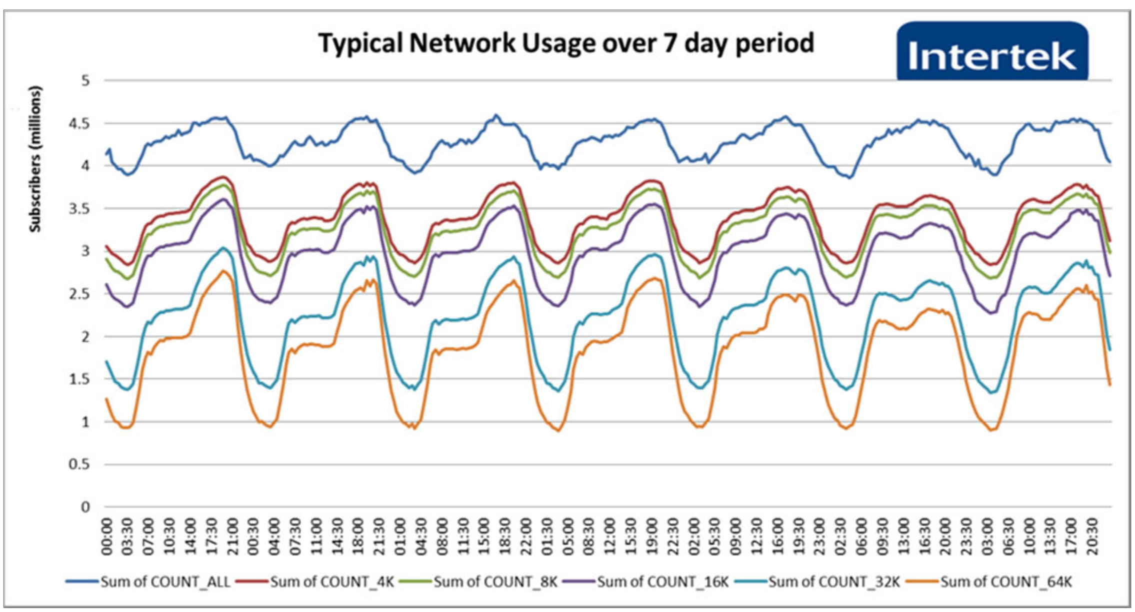

Figure 1. Network usage over a 7 day period, starting from midnight on a Monday, from the entire network infrastructure. The legend shows the specific thresholds mentioned above as 4kbps, 8kbps, 16kbps, etc. *Source:* SEAD, 2014.

Regional level analysis. Analysis from the regional data collection shows a similar pattern to the network infrastructure analysis over a weekly period. This analysis, summarized in Figure 2, is the result of 6000 households monitored on an hourly basis.

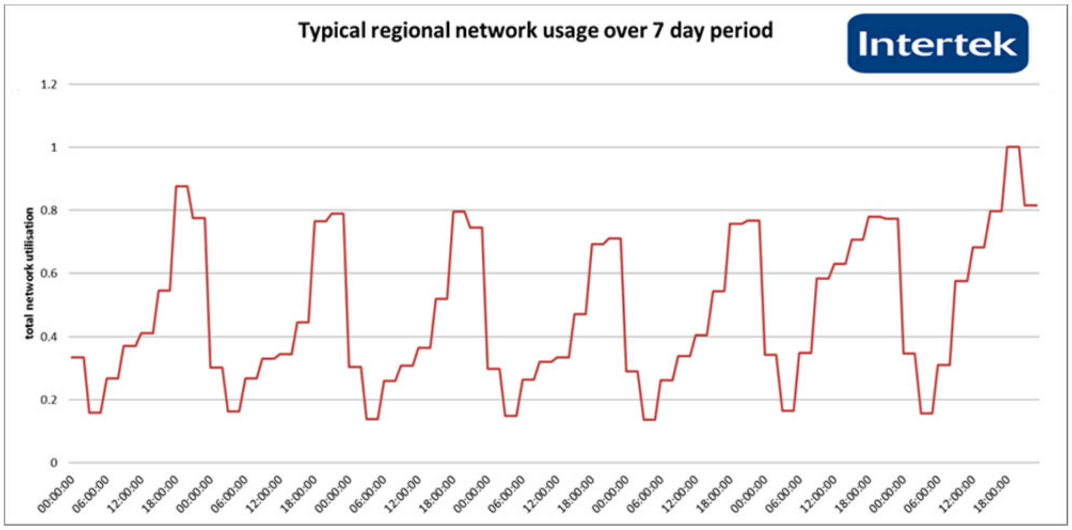

Figure 2. Network usage over a 7 day period, starting from midnight on a Monday, measured at the regional network infrastructure. There are no units for utilization – this is normalized against the peak, assigned the value 1 or 100%, with everything else measured relative to this peak. *Source:* SEAD 2014.

Detailed level analysis. The detailed level analysis revealed aggregated data from the 14 monitored households over a 45 day period, as presented in Figure 3. The total bandwidth used by all protocols for all customers was monitored at 5 minute intervals. Similar to the patterns identified at both the entire network and the regional network levels, the detailed level data shows a discernible 6 hour 'quiet period', where there is either no network activity or negligible network activity. In comparison to the aggregated network and regional data, the granular detailed data showed that the 6 hour quiet period occurs over different hours for different households. This analysis represents an energy saving opportunity at the individual level, which may not exist to the same degree at the network or regional level.

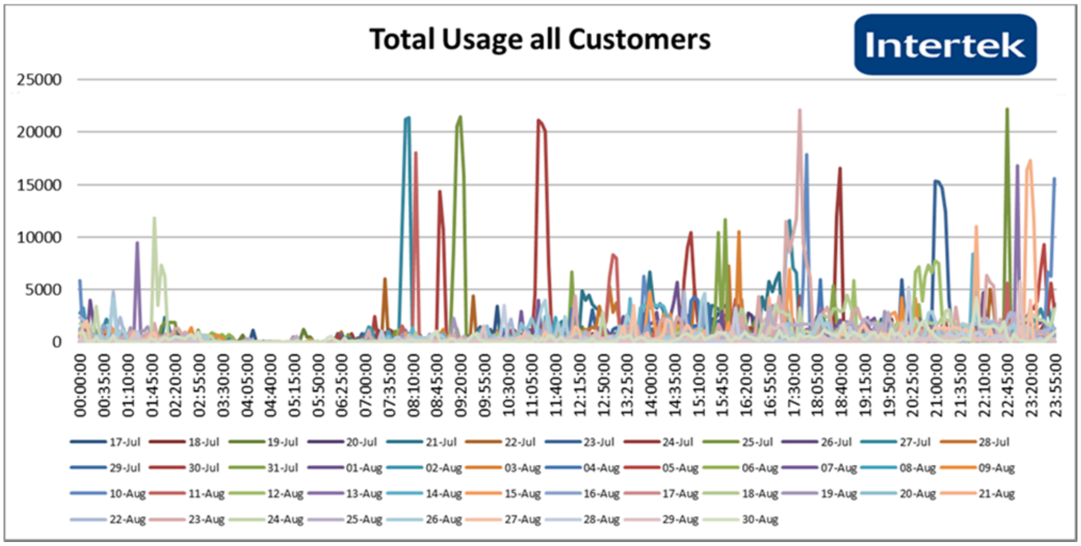

Figure 3. Total network usage by all customers measured at the individual household level, measured in kbps. *Source:* SEAD 2014.

In summary, the three-tiered analysis proffered similar results: the volume of traffic in the average UK household appears to build steadily throughout the day, peaking in the evening between 18:00 and 20:00 hours. Additional analysis showed that this trend continued, regardless of the number of networked products used in the home (Bellingham et al.).

The macro data view identified periods of negligible traffic common to the majority of users, with an expected decrease in activity over the network between 00:00 and 08:00 hours, and a period of very low traffic between 03:00 and 05:00 hours. When examined at the micro level, very low or negligible traffic occurs over a broader period in individual households, with around 6 hours of very low traffic occurring overnight on weekends, and approximately 8 hours overnight on weekdays.

These results reflect the findings in Defra's Powering the Nation report, which indicate that products generally enter a standby state during these overnight periods (Defra 2012, 350-386).

Therefore, given the extended time that products are communicating negligible data traffic or are in standby, home gateways could be switched from a high-network availability mode in to a low network availability mode over an extended period at night.

Type of Network Traffic

The DPI software enabled the project team to identify the type of data traffic flowing through the networks, by device and by protocol, at both the regional and detailed household level.

At the individual household level, the survey carried out by Ipsos-MORI provided information on the device make-up of the different households. The 14 different households were made up of the following devices:

- Set top boxes
- Audio with internet

- Wi-fi cameras
- Tablets
- Smartphones
- Blu-ray players
- Modems / routers
- Games or video consoles
- Laptops
- Desktop PCs and
- Home energy monitoring and/or control systems

Furthermore, the regional level data identified the key protocols used for internet communications. These were primarily for streaming protocols, web-video, web-browsing, peer to peer communications, and other types of protocols. Micro level data generated similar results.

The results of the analysis indicated that usage patterns show a higher percentage of time spent on web-applications where there is a higher number of network-connected products in the household.

The average daily usage by protocol studied at the individual level, presented in Figure 4 below, showed a lull in overnight activity on the network.[15]

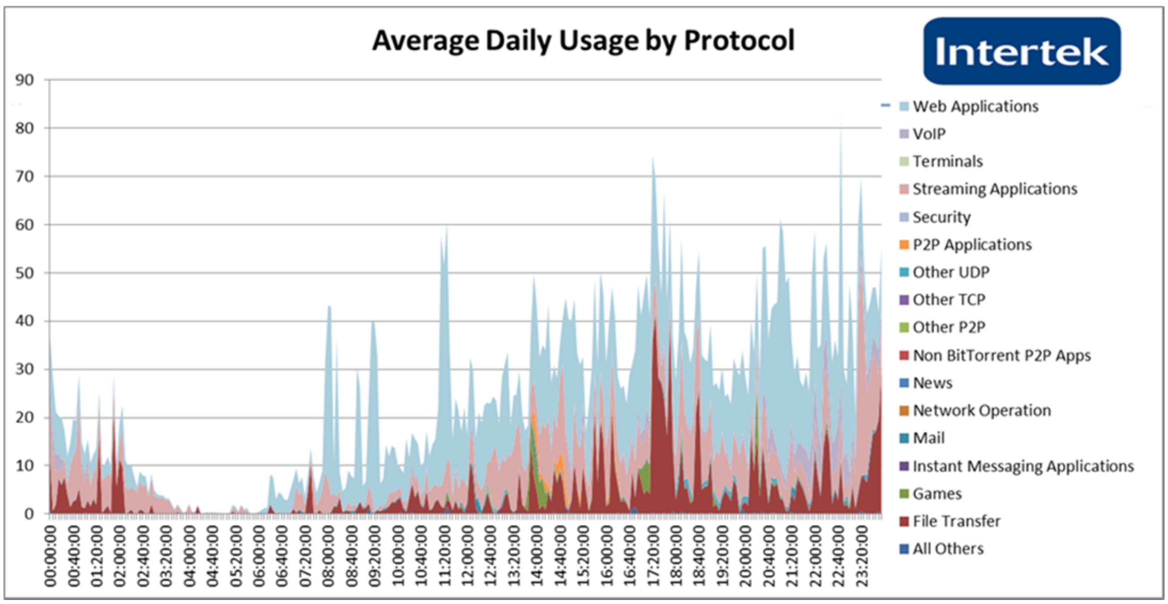

Figure 4. Average daily usage % by time and protocol from 14 customers over 45 days. *Source:* SEAD, 2014.

Potential Opportunities Identified

The UK-based analysis showed a significant period of around 6 to 8 hours of very low or negligible network traffic in each volunteer household. These results were also reflected in the macro analysis, which provided a greater statistical representation of the UK population.

The majority of home gateways or modem router integrated access devices operate at normal power levels throughout the day (unless they are turned off by the eco/cost-conscious user during the day or night). From 2015, these products will be required to switch into a lower

[15] The report presents protocol usage and types of protocols in more detail.

power mode, operating at the High Network Availability (HiNA) network standby power levels[16] defined in the amended European Ecodesign Regulations for Standby EC1275/2008.[17] Signatories to the European Code of Conduct on Energy Consumption of Broadband Equipment are also required to offer devices with low standby power consumption.[18]

If initiatives to reduce the power consumption of these products were established, for example either by incorporating internal timers or software to the products to power down either at the users request or after a period of inactivity, or by powering these products down to a Low Network Availability (LoNA) state[19], then significant savings could be achieved.

The figures below serve as a conservative estimated example of the possible savings attributed to powering down these products into a lower energy using mode:

Power saving per device = 5W (lowest figure used)
Saving occurs over 6 Hours per day (lowest figure used)
365 days per year
Annual Energy saving per device = 5 x 6 x 365 = 10,950Whr = 10.95kWhr per annum

In the UK, it is estimated that 18.9 million households use these devices, therefore a combined saving of 207 GWh per annum could be realized, without affecting user functionality of the devices.

Conclusions: Replication in the US and Other Regions

In the UK, an estimated 19 million households are equipped with home gateways or routers. This project demonstrates the potential to reduce 6 hours' worth of unnecessary energy consumption, due to near inactivity of data traffic identified in the average UK household, which could result in combined savings of around 207GWh per annum, if energy savings opportunities for these devices are adopted. It should be noted that these savings are for illustration only, and that savings could in fact be higher if other approaches were adopted during the "quiet" overnight period, as well as during the shorter periods of negligible activity occurring throughout the day. The data and opportunities outlined in this paper refer to the UK alone. The potential for energy savings could be significantly increased when considered at a global level.

In the US, recent research estimates that over 400 million network-enabled devices are connected in US homes (NPD Group, 2013). The potential energy savings are therefore much higher, and should be explored. Given the existing project methodology and templates have already been developed and piloted within the UK, the US would be well placed to build on the existing work and carry out a similar study at both the State and federal level, taking into

[16] This refers to devices where a rapid response (<1 second) to requests from the network is required.
[17] European Commission Regulation (EC) No 1275/2008 of 17 December 2008 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for standby and off mode electric power consumption of electrical and electronic household and office equipment
[18] Valid from January 2014 - available at: http://iet.jrc.ec.europa.eu/energyefficiency/ict-codes-conduct/energy-consumption-broadband-communication-equipment.
[19] This refers to devices where response times to requests from the network are less critical and can occur in >1 second .

consideration lessons learned from the UK experience. The project methodology could be further replicated in other regions to determine if similar trends exist. It is of course possible that other countries show different network traffic patterns, for example where the network-connected home is more advanced and network connections may require a constant flow of activity.

However, if other SEAD participant countries were to carry out similar projects and come to similar conclusions as those in the UK, the next step could involve identifying global opportunities to address the real world usage of unnecessary networked standby energy consumption, following in the path of the IEA's successful 1-watt initiative (Meier et al 1999).

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