IT'S NOT EASY BEING "GREEN"

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February 11, 2010

The "Internet of Things" is gathering a lot of much-needed attention to the notion of putting low-end, low-powered, special-purpose devices on the Internet.

It is important to remember that putting "things" on the Internet isn't a new concept, and nodes on the "Internet of Things" are, at their core, just nodes on the Internet. Some of them are mobile nodes, but many are fixed. Some are battery-powered, but others use wall-powered. Some use "wireless" link-layer protocols (IEEE 802.11, IEEE 802.15.4, 4G), while others use "wired" link-layer protocols (Ethernet, PLC). Most of them are fairly restricted, in terms of size or cost (processing speed, memory, etc.), when compared to today's PCs and cell phones, but many of them are far more capable than the desktop PCs we connecting to the Internet in the mid-1980s.

Within the IETF in recent years, there has been a pronounced tendency towards the development of larger, more secure, more sophisticated protocol stacks -- stacks that make greater assumptions about nodes' resources and capabilities, and that have begun to rely on the notion that most Internet nodes are "always on". To some extent, those changes within our own design criteria have created the tension that exists today, when we talk about how a small, low-power, battery-operated, intermittently connected device can function on the Internet.

The recent more wide-spread emergence of special-purpose, low-cost devices has been pushing the IETF to explore some new architectural areas, such as the energy efficiency of our protocols, as well as to stretch our definitions in some other areas, such as ease-of-use (including the notion of simple-to-use security protocols), tolerance of lossy, low-bandwidth or intermittent connectivity, etc. It has also been sending us back to our roots, a bit, by pressuring us to minimize our requirements for what constitutes a fully-functional Internet node. In my opinion, this is a healthy thing, because improvements in these areas won't only benefit the lowest-end, least functional nodes, they also may results in other benefits in other areas.

In this paper, I would like to talk briefly about energy efficiency in IETF protocols. This is an area that I believe has been largely ignored by the IETF in the past, and one where we could achieve significant benefit by raising widespread IETF awareness of the issues involved.

In discussions about "The Internet of Things" we tend to focus on low-end, battery-operated nodes take active steps (such as using low-power wireless links, and sleeping periodically) to achieve an acceptable battery life. We focus on the energy efficiency of our lower-layer protocols (IPv4, IPv6, ND), because those nodes often run small, proprietary or highly-tuned applications above IP.

It is likely, however, that energy efficiency in higher-layer protocol will become an issue, even for wall-powered nodes, when those nodes are installed in sigificant numbers. This may be especially true in "Smart Energy" installations, where the purpose of the nodes is to save energy, thus it is of paramount importance that they don't consume more energy than they save.

The advances we make in increasing the energy efficiency of our protocols, across the board, could also provide advantages for larger battery-operated devices, such as laptops and cell phones, and could potentially lead to a significant energy savings for all Internet-connected nodes. With today's focus on "green" devices, we would do well to work on protocols that enable all devices to use less energy.

Getting back to the "Internet of Things", though, there are a couple of approaches that special-purpose devices employ to save energy, and the IETF should work on developing protocols that are consistent with, or compatible with, these practices:

- Reducing the number of packets/bytes that are communicated in order for IETF protocols to function. Since wireless communication can be a large portion of the power-budget for wireless devices, reducing unnecessary communication can significantly increase the battery life of a low-end device.

- Sleeping periodically, and often agressively, when not in use. In some cases, these nodes will only wake periodically to handle needed communications.

Unfortunately, being consistent with these approaches will require some changes to the way we currently do things, in many cases.

The IETF has developed a number of protocols that expect or require a node to maintain a persistent presence on the network in order to respond to periodic messages that are required in order to maintain persistent sessions, connections, security associations, or state. These protocols work well on networks with sufficient network bandwidth, where there is a low cost to receiving/sending messages, and nodes are persistently avaialable on the network. However, they do not work well, at all, when the cost of sending/receiving those messages are high (in terms of bandwidth or battery life) or in cases where nodes sleep periodically and are not persistently available to receive those messages.

We also have a number of protocols that are based on the concept of polling a set of nodes periodically to understand their state (such as SNMP in its common operational mode) or on broadcasting/multicasting information to a set of nodes periodically (such as Neighbor Discovery (ND), IPv4 Address Autoconfiguration, etc.). These mechanisms use a relatively large amount of network bandwidth, consume power in nodes that receive the messages even when they don't need to respond, and are not compatible with the notion that low-power nodes may be sleeping most of the time, and unable to receive these periodic messages.

These issues can be addressed by designing IETF protocols that are sleep-compatible, and that minimize or eliminate unnecessary message exchanges. In many cases, these changes would also reduce the cost of using these protocols on more conventional links/equipment, and allow laptops and other higher-end battery-operated devices to work better as they hibernate and return from hibernation.

SLEEP-COMPATIBILITE PROTOCOLS

As discussed above, protocols that expect Internet nodes to have a persistent presence on the network do not work well with nodes that spend much of their time asleep.

In some cases, protocols can be easily modified to switch to a paradigm where end-nodes poll for recent messages or events when they rejoin the network. In other cases, an entirely new protocol may be needed to support that type of operation. As we design new protocols, or make major extensions to old ones, we should consider the needs of sleeping nodes, and how they will rejoin and participate in our protocols when they are awake.

MINIMIZING PACKET EXCHANGES

We have many IETF protocols that periodically poll for information from a set of attached nodes and/or send periodic multicast/broadcast packets that are needed for the protocol to function. In some cases, these protocols are very verbose and would, if run unmodified on a low-bandwidth, low-power network, consume a large percentage of the network bandwidth on an ongoing basis and/or substantially reduce the battery life of the attached devices.

In some cases, these protocols could be adapted to work better with low-power nodes and/or nodes that sleep periodically, by changing their paradigm from one where the network infrastructure periodically queries the attached devices, to one where the devices confirm their presence on a negotiated schedule and receive necessary messages (if any) at that time. In other cases, protocols might require substantial rework to be more mindful of their bandwidth use.

EXISTING/FUTURE WORK

Work is currently underway in the the 6LOWPAN working group develop a new version of ND (called 6LOWPAN-ND) that reduces or eliminates the problems described above, however that work is 6LOWPAN specific. It is possible that we shoudl consider a more general solution to this problem in ND.

Work is also underway in the ROLL and 6MAN working groups to develop a hop-by-hop routing protocol that is consistent with low-bandwith, low-power networks and sleeping nodes.

However, there are other IETF protocols that have the same issues, and the concerns outlined above would need to be considered in order for them to be used on low-bandwidth and low-power networks and/or with sleeping nodes. These include most of our autoconfiguration protocols (IPv4 Autoconfiguation, Multicast DNS and others), our primary device management/configuration protocols (SNMP and NETCONF) and many others.

The IETF should consider the energy efficiency of any new protocols that we design, not only to make them more consistent with low-bandwidth, low-power networks, but in order to save energy throughout the Internet. Which should also understand the design principles that are need to allow our protocols to be more compatible with all types of nodes that sleep periodically from $10 thermostats to high-end laptops.

A BIT ABOUT ME

Margaret Wasserman has been desiging and producing embedded Internet hardware and software since 1990. In the early 1990s, she was primarily responsible for developing a small and highly-efficient IPv6 implementation for resource-contrained embedded devices. Since that time her products have been used on various embedded devices from gas pipleline computers, to traffic lights, to early Palm Pilots, to RFID readers. At the present time she is consulting with Belkin on the development of consumer-oriented Smart Energy equipment.