State of the Art

Kashyap, Shruthi; Rao, Vijay; Venkatesha Prasad, Ranga Rao; Staring, Toine

DOI
10.1007/978-3-030-85836-0_4

Publication date
2021

Document Version
Final published version

Published in
SpringerBriefs in Applied Sciences and Technology

Chapter 4
State of the Art

With the advent of the Internet of Things (IoT) concept, a lot of research is being made to find ways of establishing connectivity between diverse and distinct objects that are based on dissimilar technologies. NFC is a widely used technology which has gained a lot of popularity because of its features like increased security, instant connection procedure, low power, low cost, etc. Over the last few years, there has been some research on providing Internet connectivity to NFC-enabled IoT devices. For the ease of comparison and analysis, the methods of enabling connectivity in the related works are broadly classified into the following types:

1. Tunneling standard TCP/IP protocol over NFC.
2. 6LoWPAN adaptation for TCP/IP protocol over NFC.
3. TCP/IP adaptation mechanisms for high delay networks.

4.1 Tunneling Standard TCP/IP Protocol over NFC

One of the most straightforward ways of providing Internet connectivity to a device through the NFC channel is by tunneling the TCP/IP protocol over the channel. Echevarria et al. [1] introduce a concept called WebTag, which enables direct IP-based access to a sensor tag using NFC technology. It supports secure applications by tunneling the TCP/IP traffic over the NFC carrier. In this method, the sensor tags are equipped with a full TCP/IP suite, web server and an NFC communication channel that connects them to the NFC reader device which behaves like a network gateway. The paper briefly discusses the performance issues caused by bandwidth constraints, increased transmission latency due to differing processing speeds in components, memory limitations, etc. To overcome these challenges, it employs a data fragmentation mechanism, where large packets are fragmented/defragmented at the ends of the NFC channel. It also uses the Van Jacobson packet compression technique [2] to further reduce the latency. Although the paper gives an overview

S. Kashyap et al., *Cook Over IP*,
SpringerBriefs in Applied Sciences and Technology,
https://doi.org/10.1007/978-3-030-85836-0_4

of the effects of tunneling the TCP/IP over NFC, it lacks a detailed analysis of the TCP characteristics that affect the system performance. It uses the uIP stack [3] with standard configuration and does not give enough insight on how the stack can be adapted to the NFC technology to achieve the best results. Furthermore, the paper deals with a scenario where full bandwidth of the NFC channel is available for transmission, unlike the cordless kitchen project where only the slotted bandwidth of NFC is used. So the effects of establishing a TCP/IP connection over a discontinuous channel cannot be realized with the results provided by this paper.

Grunberger et al. [4] propose a concept for a test system that can establish a TCP/IP connection over the NFC channel and tunnel all the TCP/IP data through it. The communication protocol stack used in the system is split into two separate blocks that are connected via Bluetooth. The NFC block hosts the physical (NFCIP-1) and Logical Link Control Protocol (LLCP) layers of the NFC stack, and a PC block is used for the higher TCP/IP layers. The system has the full available bandwidth of the NFC channel, however, as it uses the standard NFC protocol the Protocol Data Unit (PDU) of NFC is limited to 255 bytes. To overcome this limitation, a chaining mechanism is used to transfer large TCP/IP packets, similar to [1]. To reduce the latency, the system ensures that data is transmitted over NFC as soon as the channel is free. It does not employ any compression technique as it mainly focuses on analyzing the performance of the system. The paper provides some test results in terms of TCP retransmission rate and measured data rate using three different configurations of the IP Maximum Transmission Unit (MTU) sizes. However, it does not give a detailed analysis or results taking other aspects of the TCP/IP protocol into account. Although the paper highlights some factors affecting the system latency such as slow data processing in the NFC device and long reaction times due to varying processing speeds in components, it fails to discuss the mitigation techniques or ways of modifying the TCP/IP stack to overcome these challenges. It just gives a preliminary analysis to show the advantages and disadvantages of tunneling TCP/IP over NFC devices.

4.2 6LoWPAN Adaptation for TCP/IP Protocol over NFC

A design space and use-case analysis of transferring IPV6 packets over NFC for resource-constrained IoT devices is provided in [5]. The paper recommends using the 6LoWPAN technology [6] for applications involving constrained node networks such as NFC. 6LoWPAN stands for Internet Protocol (IPv6) over Low-Power Wireless Personal Area Networks (LoWPAN). It is a low-power wireless mesh network which allows devices with limited processing capability to connect directly to the Internet using open standards.

The 6Lo group from the Internet Engineering Task Force (IETF) has been working on standardizing the mechanism for transmitting IPv6 over resource-constrained networks such as NFC [7], Bluetooth Low Energy (BLE) [8] and IEEE 802.15.4 [9]. Youn et al. [7] is an Internet draft from the 6Lo working group that describes a method of remodeling the IPV6 stack to include the data link and the physical layers of the NFC stack by adding 6LowPAN functionalities such as neighbor discovery, address auto-configuration, header compression and fragmentation. In this method, the IP packet is transmitted as the PDU of the NFC LLCP layer.

Park et al. [10] propose a 6LoWPAN adaptation protocol for transmitting IPV6 packets over NFC devices. It involves modifying the standard TCP/IP stack to enable IPV6 communication over the NFC channel using 6LoWPAN techniques described in [7]. The paper provides some simulation results in terms of latency and total packet count. It claims that by using the adaptation layer, the NFC device takes negligible additional time for initialization. It compares the number of IPV6 packet transmissions with and without IP header compression and concludes that the reduction in the number of packet transmissions will be higher for large packet sizes. Other aspects of the performance have not been discussed in detail.

As cordless appliances are resource-constrained IoT devices, using the 6LoWPAN adaptation protocol could be beneficial for the performance. But before directly adopting this technique, it is very important to study the cordless kitchen environment involving the time-slotted NFC channel and analyze how the TCP/IP communication behaves when subjected to such a discontinuous and constrained channel. None of the above works gives insight into this aspect. Furthermore, the works do not provide detailed analysis in terms of the behavior of standard handshake, acknowledgment, retransmission and congestion control mechanisms of TCP over a time-multiplexed NFC channel. They do not study the NFC channel characteristics and quantify the performance based on latency, throughput, retransmissions and bandwidth utilization for different NFC bit rates and Bit Error Rates (BER).

Once an analysis on this level is done, the main bottlenecks of tunneling a heavy-weight protocol like TCP/IP over a constrained channel like time-slotted NFC can be realized. And once these limitations are addressed, techniques like 6LoWPAN and Constrained Application Protocol (CoAP) [11] can be used to further improve the system performance.

4.3 TCP/IP Adaptation Mechanisms for High Delay Networks

There has been some research on the performance of TCP over slow links. Benkö et al. [12] provide a detailed end-to-end TCP performance analysis in GPRS networks in terms of round trip delays, throughput, packet loss ratios, etc. It also quantifies the performance improvements with various TCP parameters like maximum segment size, receiver window size, selective acknowledgments and timestamp usage. Some of the theoretical research aspects in this paper could be mapped to the cordless kitchen system, however, the practical results cannot be used or compared with the cordless kitchen as they deal with completely different wireless technologies.

Katabi et al. [13] propose a new protocol called Explicit Control Protocol (XCP) which gives an improved congestion control mechanism in very high bandwidth-delay product networks. The work mainly concentrates on improving the bandwidth utilization and fairness in bandwidth allocation in addition to reducing the standing queue sizes and packet drops. It describes a congestion feedback mechanism that requires additional fields in the protocol header to carry congestion-related information. As the NFC protocol only supports one-to-one communication, techniques related to fairness control are not applicable to the cordless kitchen system. The congestion feedback mechanism could be used, but the additional overhead in the protocol header could increase the latency on the constrained NFC channel.

Dawkins et al. [14] is an Internet draft from the IETF that gives a generalized overview on the performance implications of slow links on the TCP/IP protocol. It recommends header and payload compression techniques to reduce the latency, TCP buffer auto-tuning to avoid packet drops due to buffer overflow conditions and limited transmit algorithm to trigger fast retransmit and fast recovery in case of packet loss. Leung et al. [15], Klein et al. [16] and Fotiadis et al. [17] provide a couple of techniques to improve the throughput of TCP in wireless networks with high delay variability. They mainly discuss spurious retransmissions that occur in such networks and provide mitigation techniques.

All these works provide some aspects of the TCP/IP behavior in high delay, low bandwidth links but none of them studies the performance of a system containing different types of wireless channels with dissimilar characteristics. There has been no research on slotted TCP mechanisms, where TCP/IP is subjected to a discontinuous communication medium. Some of the techniques proposed in the related work could be used in the cordless kitchen once the TCP protocol is appropriately tuned to the system. This research mainly focuses on adapting the standard TCP/IP protocol stack to the time-multiplexed NFC channel by addressing some major performance bottlenecks. It also provides a detailed analysis of the behavior of important TCP mechanisms in such an environment.

References

1. J.J. Echevarria, J. Ruiz-de-Garibay, J. Legarda, M. Álvarez, A. Ayerbe, J.I. Vazquez, WebTag: web browsing into sensor tags over NFC. Sensors 8675–8690 (2012). https://doi.org/10.3390/s120708675
2. V. Jacobson, Compressing TCP/IP headers for low-speed serial links. RFC **1144**, 1–49 (1990)
3. Wikipedia contributors. UIP (micro IP). Wikipedia (2021). https://en.wikipedia.org/wiki/UIP_(micro_IP)
4. S. Grunberger, J. Langer, Analysis and test results of tunneling IP over NFCIP-1, in *2009 First International Workshop on Near Field Communication* (2009). https://doi.org/10.1109/nfc.2009.21
5. Y. Hong, Y. Choi, M. Shin, J. Youn, Analysis of design space and use case in IPv6 over NFC for resource-constrained IoT devices, in *2015 International Conference on Information and Communication Technology Convergence (ICTC)* (2015). https://doi.org/10.1109/ictc.2015.7354725

6. N. Kushalnagar, G. Montenegro, C.P. Schumacher, IPv6 over low-power wireless personal area networks (6LoWPANs): overview, assumptions, problem statement, and goals. RFC **4919**, 1–12 (2007)
7. J. Youn, Y. Hong, D. Kim, J. Choi, Y. Choi, Transmission of IPv6 packets over near field communication (2000)
8. J. Nieminen, T. Savolainen, M. Isomäki, B. Patil, Z. Shelby, C. Gomez, IPv6 over BLUETOOTH(R) low energy. RFC **7668**, 1–21 (2015)
9. G. Montenegro, N. Kushalnagar, J. Hui, D. Culler, Transmission of IPv6 packets over IEEE 802.15.4 Networks. RFC **4944**, 1–30 (2007)
10. J. Park, S. Lee, S. Bouk, D. Kim, Y. Hong, 6LoWPAN adaptation protocol for IPv6 packet transmission over NFC device, in *Seventh International Conference on Ubiquitous and Future Networks* (2015), pp. 541–543
11. Wikipedia contributors. Constrained application protocol. Wikipedia (2021). https://en.wikipedia.org/wiki/Constrained_Application_Protocol
12. P. Benkö, G. Malicskó, A. Veres, A large-scale, passive analysis of end-to-end TCP performance over GPRS. IEEE INFOCOM 2004 **3**, 1882–1892 (2004)
13. D. Katabi, M. Handley, C. Rohrs, Congestion control for high bandwidth-delay product networks. SIGCOMM '02 (2002)
14. S. Dawkins, G. Montenegro, M. Kojo, V. Magret, End-to-end performance implications of slow links. RFC **3150**, 1–17 (2001)
15. K. Leung, T. Klein, C. Mooney, M. Haner, Methods to improve TCP throughput in wireless networks with high delay variability [3G network example], in *IEEE 60th Vehicular Technology Conference, 2004*. VTC2004-Fall, vol. 4 (2004), pp. 3015–3019
16. T. Klein, K. Leung, R. Parkinson, L.G. Samuel, Avoiding spurious TCP timeouts in wireless networks by delay injection, in *IEEE Global Telecommunications Conference, 2004*. GLOBECOM '04, vol. 5 (2004), pp. 2754–2759
17. G.I. Fotiadis, V. Siris, Improving TCP throughput in 802.11 WLANs with high delay variability, in *2005 2nd International Symposium on Wireless Communication Systems* (2005), pp. 555–559