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A Comparative Study on Available IPv6 Platforms for Wireless Sensor Network

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***Abstract*—**The low power wireless sensor devices which usually uses the low power wireless private area network (IEEE 802.15.4) standard are being widely deployed for various purposes and in different scenarios. IPv6 low power wireless private area network (6LoWPAN) was adopted as part of the IETF standard for the wireless sensor devices so that it will become an open standard compares to other dominated proprietary standards available in the market. 6LoWPAN also allows the integration and communication of sensor nodes with the Internet more viable. This paper presents a comparative study on different available IPv6 platforms for wireless sensor networks including open and close sources. It also discusses about the platforms used by these stacks. Finally it evaluates and provides appropriate suggestions which can be use for selection of required IPv6 stack for low power devices.

***Keywords*—**6LoWPAN Stacks, 6LoWPAN Platforms, m-Stack, NanoStack, uIPv6, PhyNet 6LoWPAN, Jennic 6LoWPAN.

I. INTRODUCTION

CURRENT trends have directed the usage of wireless sensor network for various purposes. The applications of using this technology are endless from agriculture to health monitoring to military purposes. The low power wireless sensor devices which usually uses the low power wireless private area network (IEEE 802.15.4) standard are being widely deployed for various purposes and in different scenarios. The biggest challenges in the deployment of these sensor devices, also called as motes, are to efficiently use the low power and low bandwidth.

IPv6 makes communication to become more visible across various networks and various devices. IPv6 low power wireless private area network (6LoWPAN) was adopted as part of the IETF standard for the sensor devices so that it will become an open standard compares to other dominated proprietary standards available in the market. 6LoWPAN is not restricted to IEEE 802.15.4 standard rather can use other layer two standards as well. The deployment of IP base wireless sensor network is a next step to integrate this technology with the Internet devices for global connectivity and provides end to end communications.

II. DISCUSSION

This section now discusses about following available IPv6 platforms for wireless sensor network:

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A. uIPv6

uIPv6 is a next version of uIP which was an implementation of IPv4 on WSN. uIPv6 is the smallest certified IPv6 stack for low power and low processing tiny devices reminiscent of actuator and sensor nodes. It is an open source and licensed under BSD license that allows it to be used in both open and closed source projects.

uIPv6 is one of the smallest IPv6 stack available which has ROM size of 11.5 Kbytes and RAM size of 1.8 Kbytes. It can be use with resource constrained platforms due to lesser requirements. uIPv6 stack is built on top of Contiki operating system [5] but due to its modular design can also be use with other operating systems. Total memory utilization in conjunction with Contiki requires to have 35KB of ROM and 3KB of RAM. Contiki with uIPv6 runs on Atmel Raven, Tmote Sky/TelosB, and number of other AVR-based and MSP430-based platforms. It is also tied up with UDP and TCP protocol implementations [2]. Fig. 1 demonstrates uIPv6 over layer two protocols.

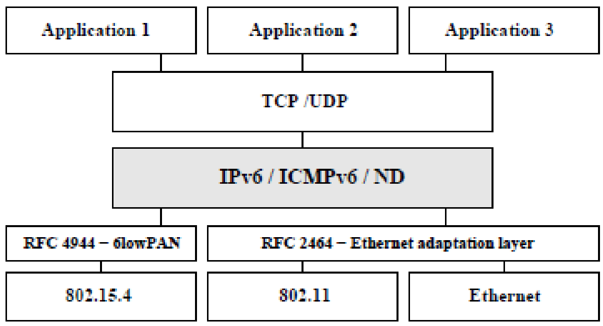

Fig. 1 uIPv6 over different L2 protocols [2]

The uIPv6 stack implemented all the musts of RFC4294 IPv6 node requirements except for multicast listener discovery support and redirect function support [7]. It implements header compression, fragmentation and addressing as defined in RFC4944 [7]. As it conforms to IETF 6LoWPAN specification, it can be interoperable with Arch Rock and Sensinode 6LoWPAN implementations. uIPv6 implements route over technique as compare to mesh under-related features. It has also employed the new 6LoWPAN header compression scheme [8]. It uses a single global buffer for incoming and outgoing packets. The length of the buffer is the length of the MAC header in addition to 1280 bytes (i.e., the minimum link MTU). Additional buffers are available to support fragmentation reassembly and per neighbor packet buffering. The main data structures are the interface address list and the neighbor cache, prefix list, and default router list which are required by ND [2].

It has been evaluated by using Atmel RAVEN board which has atmega1284P MCU with 128 KB of flash and 16 KB of SRAM. The code was compiled using avr-gcc 4.2.2 which provides the IPv6 code size approximately of 11.5 KB and RAM around 1.8 KB [2]. The single packet buffer uses 1296 bytes; the neighbor cache takes 140 bytes (35 per neighbor stored), the prefix list takes 69 bytes (23 per prefix), the router list takes 14 bytes (7 per router) and the interface address list and variables 109 bytes.

B. Arch Rock PhyNet

Arch Rock was founded in May 2005 with a research effort of University of California, Berkeley and Intel Research. Arch Rock is one of the pioneers of introducing technology by which wireless sensor network can be accessed and operated as a complete solution integration with the IT infrastructure. The company focuses on both Zigbee and 6LoWPAN based products. In March 2007, Arch Rock released the first commercial implementation of IETF 6LoWPAN standard. The company branded their IP-based WSN technology with PhyNet^{TM}. Arch Rock has become first wireless sensor network vendor to earn IPv6 Forum’s IPv6 ready phase 2 designation [12].

Arch Rock 6LoWPAN stack conforms to IETF 6LoWPAN standards as well as introduces additional features such as proprietary routing protocol. “The standard Arch Rock routing protocol utilizes a Rendezvous Point (RP), typically on the 6LoWPAN router. Based on a distance-vector protocol, the routing protocol is responsible for picking a default route to the RP. To guard against variations in wireless connectivity, two successor default routes are maintained and used whenever the primary route fails. This adaptive beaconing approach keeps the network robust in volatile environments while minimizing control overhead in stable conditions.”[3]

There are some enhancements done on MAC layer by Arch Rock for all time availability; “Arch Rock’s low-power link layer that operates on IEEE 802.15.4 radios. The link layer implements a protocol based on sampled listening that does not require scheduling, synchronization, or any build-up of context before IP packets are sent to neighboring nodes. Because a node can choose to unicast to a neighboring node or even broadcast to all neighbors at any time, without waiting for specific time-slots, an illusion of “always on” is created. This allows the network to have rapid response times, critical for network management and mobility applications. Arch Rock’s low-power link layer allows additional optimizations through adjustments in sample period, shifting the energy burden between nodes.” [3]

Arch Rock software stack is based on mature version of TinyOS which is supported on their hardware platforms by preserving the full capabilities of each platform. Moreover simple driver framework for new sensors across multiple platforms is also incorporated into the platform. Arch Rock also used sophisticated compiler optimization techniques for performance and reliability of system.

Fig. 2 illustrates the Arch rock sensor node which is integrated with temperature, humidity, photo-synthetically active radiation and total solar radiation sensors. It also has expansion port which allows adding of numerous types of additional sensors. Fig. 3 illustrates PhyNet router which has IEEE 802.15.4, WiFi and Ethernet. PhyNet router allows the connectivity of deployed sensor nodes with external IP network through WiFi or Ethernet interfaces.

Fig. 2 Arch Rock IP sensor node

Fig. 3 Arch Rock PhyNet Router

Fig. 4 illustrates the Arch Rock’s PhyNet server which provides a web based console setup, configuration and management of multiple wireless sensor networks and routers. It also allows to re-program heterogeneous nodes with pre-compiled embedded applications over the air.

Fig. 4 Arch Rock PhyNet server

C. Sensinode

Sensinode, a Finnish company is a result of ten years of research in IP based wireless embedded systems. They are one of the pioneering IP-based wireless sensor network solution providers which integrated the wireless sensor nodes with the Internet. NanoStack is a flexible 6LoWPAN stack with a full IEEE 802.15.4 implementation developed by Sensinode. There are two versions of NanoStack; NanoStack 1.x and 2.x respectively. NanoStack 1.x is an open source platform and the new NanoStack 2.0 is a proprietary next generation platform for 6LoWPAN. Fig. 5 illustrates the NanoStack architecture.

The 6LoWPAN NanoStack implementation conforms to standard specification of RFC 4944. It uses widely and easy to use socket interface model for data communications for application. The NanoStack API follows POSIX API and adds memory management features. It supports both Linux and Windows development environments using open source tools for example gcc, make and sdcc. The NanoStack is constructed on open source based portable real time operating system called FreeRTOS. FreeRTOS, a microkernel operating system provides a scheduler, memory allocation, queues and semaphores with system timer functionality [6]. NanoStack extends the timing functionality of basic FreeRTOS API by implementing extensions like asynchronous timer service. It does not modify the source tree of FreeRTOS which allows the users to upgrade the FreeRTOS without the need of update patches for the source code. FreeRTOS executes NanoStack as a single task which allows it to utilize less RAM and effective flow control.

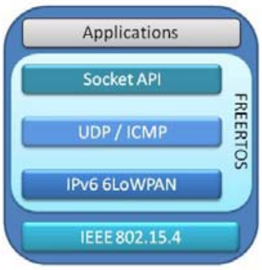

Fig. 5 Nanostack

Sensinode's NanoMesh is a multi-hop forwarding technique for extending 6LoWPAN network by using mesh-header feature of 6LoWPAN. The algorithm makes forwarding decision by considering a combination of overhearing and limited flooding methods. It makes use of built-in neighbor and routing tables features of NanoStack. NanoMesh also supports self healing and the discovery of gateways. It supports 2-3 hops with fast mobility.

NanoStack 1.1, is an open source 6LoWPAN stack implemented IEEE 802.15.4 standard and has built-in radio chip drivers for TI CC2420 and CC2430 radios. NanoStack 2.0 is a proprietary 6LoWPAN stack by Sensinode which is a platform and radio independent and has support for CC2530 (2.4GHz) and CC1110 (868/915MHz) from Texas Instruments. NanoStack 2.0, a proprietary 6LoWPAN stack introduces new features in addition to NanoStack 1.1 base stack including robust routing.

Fig. 6 shows a Nano Sensor node which has TI CC2431 SoC processor and has built in 3-axis accelerometer, temperature and light sensors. Fig. 7 illustrates a NanoRouter which uses IEEE 802.15.4 and has CC2431 SoC processor. Moreover it can also be reprogrammed. Fig. 8 illustrates a new NanoRouter Pilot based on Linux 2.6 Kernel and ARM9 180MHz processor. It has high power IEEE 802.15.4 2.4GHz and 868/915 MHz radios and Ethernet with PoE support with management features. Both routers allow the functionality to connect wireless sensor network with the IP network.

Fig. 6 Nano Sensor

Fig. 7 Nano Router

Fig. 8 Nano Router Pilot

D. Jennic

Jennic is a semiconductor company based in Sheffield UK, provides low cost and highly integrated microcontrollers for broad range of applications with focus on IEEE 802.15.4, ZigBee and 6LoWPAN.

Jennic's 6LoWPAN protocol stack conforms to IETF standards and provides a wireless connectivity solution based on IEEE 802.15.4 standard at 2.4GHz. The stack is designed to work with Jennic's JN5139 wireless microcontroller, a low power single chip for the development of wireless networking products. JN5139 is a 32-bit RISC processor with 192 KB of ROM and 96 KB of RAM.

It supports point to point and star connectivity based on IEEE 802.15.4 standard and provides an alternate solution based on Jennic's JenNet networking stack which provides highly stable self-healing cluster tree solution. The development kits includes a Jenie API which is highly abstracted C based software API to reduce complexity of wireless sensor network for designers to focus on functionality and faster application development. It can support up to 100 nodes within a cluster and provides automatic route formation and repair. The stack is architectured to support multiple low power clusters. Fig. 9 illustrates the Jennic 6LoWPAN stack.

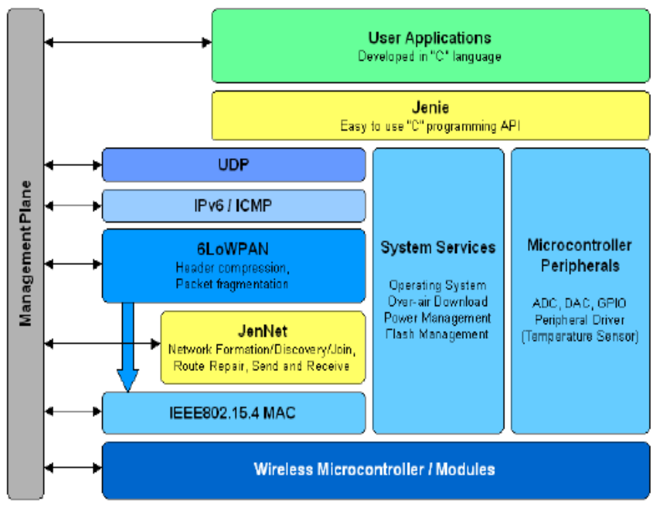

Fig. 9 Jennic 6LoWPAN Stack[12]

E. m-Stack

m-Stack is a 6LoWPAN stack compliant with RFC4944 with two routing options, DYMO mesh networking and flood multihop delivery support. It supports CC243x SoC and customs solutions. m-Stack footprint is 50-60KB of flash and 2-5 KB of RAM depends on compile time configurations. WBXML web based services are also available. There is a commercial and free non-commercial available solution available with variant features. Fig. 10 shows m-Stack 6LoWPAN stack. [7]

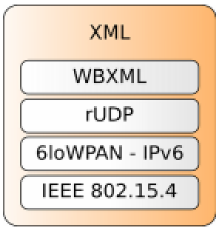

Fig. 10 m-Stack [7]

III. CONCLUSION

By exploring different currently available 6LoWPAN stacks on different embedded platforms we can understand their technical details and specifications. This paper discusses about open source 6LoWPAN stacks like uIPv6 and NanoStack which may allow research community to customize and experiment 6LoWPAN platform on different use cases such as agriculture and logistics. Moreover it also explored currently available commercial 6LoWPAN platforms which demonstrate different useful features.

TABLE I
COMPARISON OF IPV6 PLATFORMS [2] [10] [12] [13] [14] [15] [16]

Stack	License	OS	Hardware				Footprint		Multihop
			MCU	Radio	ROM	RAM	ROM	RAM	
uIPv6	Open Source	Contiki	Atmel Raven (8 bit) TI MSP430 (16 bit)	AT86RF230 CC24xx	128K 128K	8K 8-16K	11.5K	2K	AODV
Arch Rock PhyNet	Proprietary	Tiny OS 2.0	TI MSP430 (16 bit)	CC2420	128K	10K	10K	2K	Arch Rock routing protocol
NanoStack	Open Source and Proprietary	FreeRTOS	TI MSP430 (16 bit)	CC24xx CC25xx	128K	8K	10K	2K	NanoMesh
Jennic	Proprietary	Proprietary	JN5139 (32 bit)	JN5139	192K	96K	-	-	JenNet
m-Stack	Free for non commercial usage	Proprietary	-	CC243x	-	-	50K	2K	DYMO or Flood multihop delivery

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