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Persistent Wi-Fi Prototype Network Router

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Abstract

EPRI has developed a router with multiple Service Set Identifiers (SSID) to support the EPRI patent pending Persistent Wi-Fi connectivity methodology. Additionally, EPRI has identified requirements for commercially available off-the-shelf Wi-Fi routers that may also operate in this configuration. A description, requirements and results of the routers enabled with this technology are described

Keywords
Service Set Identifier (SSID)
Wi-Fi Router
Persistent Wi-Fi

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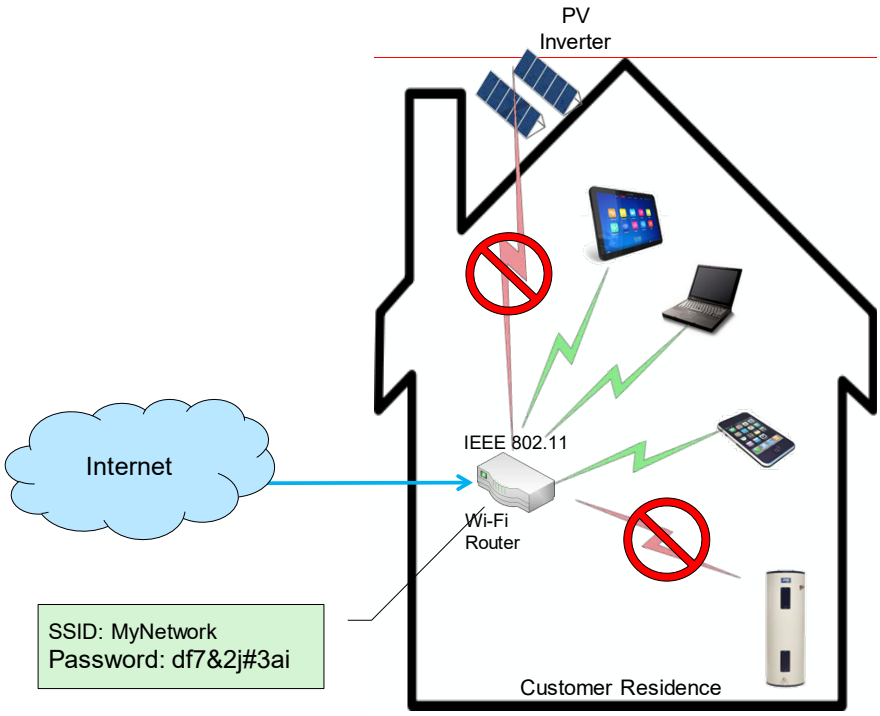
Section 1: The Requirements for Persistent Customer Connectivity

Since many of the electric utility Smart Grid and Integrated Grid systems rely on communications to devices at the customer premises it makes sense to identify those devices that the utilities desire to remotely access and/or control. Some examples of these devices could be load control switches, smart Wi-Fi™ circuit breakers, connected home displays, EV charging stations, PV inverters, or battery storage systems. Utility connectivity originally provided through the electric utility meters has not been successful for several reasons, such as limited range or RF impediments, low data throughput, and customer interaction required for setup and provisioning. With the surge of gaming, streaming video, and telephony over the internet, the ubiquitous Wi-Fi router on the customer premises had to become even more robust in speed and device connectivity. Even more pressure was to add new Wi-Fi devices for energy monitoring and smart home and/or IoT applications.

In an EPRI publication *3002009798 Wi-Fi Persistent Network for Customer Connectivity*, *EPRI, Palo Alto, CA 2017*, Tim Godfrey fully describes the software concept of the patent pending persistent Wi-Fi connectivity technology [1]. He describes issues with directly connecting to customer Wi-Fi, the process of setting up or configuring the device, and establishing a secure network name (SSID) as well as entering a security key.

There is an industry need for a Wi-Fi connection for energy devices at the customer premises that offers easy provisioning and setup, and then provides a permanent, secure connection to the utility services they are associated with as shown in Figure 1-1.

Figure 1-1 portrays the loss of connectivity to energy devices from a single SSID router at the customer site if the customer makes changes to the network name.



[image used with permission]

Figure 1-1
Loss of Connectivity Due to Network Changes

Two Wi-Fi router devices were chosen based on the hardware required to set-up the technology. The first was an EPRI developed integrated multi-protocol Wi-Fi router used in many areas of EPRI research. The second a commercially available Wi-Fi router from LINKSYS.

Section 2: EPRI Designed Multi-Protocol Router

The EPRI Multi-Protocol Router MPR4 Rev D was designed for a primary research tool for EPRI engineers to advance the state of the art in connected devices. The features of the device are:

PROCESSOR

- RM9 CPU with Linux OS: Atmel AT9SAM9x25 400MHz CPU, 1Gb DDR-SDRAM, 2Gb NAND Flash
- Integrated 10/100 dual-speed Ethernet MAC
- Integrated CAN2.0b Support

INTERFACES

- Protocols Supported:
  - Wi-Fi (IEEE 802.11 a/b/g/n with dual band support and dual SSID with external antenna
  - Cellular LTE CAT1 LTE/4G – QPSK, 16QAM for use with Verizon 4G LTE network
  - GreenPHY (using QCA7000 chipset) with pilot line OR AC line coupling
  - CAN (SAE J1939) via 6 pin sealed Molex connector on front panel
  - ZigBee (IEEE 802.15.4) with external antenna
  - Bluetooth low energy module with on-board antenna
  - USB 2.0 A & B
  - RS232, RS485, 3x PWM in, 3xPWM out, 3xAnalog in
- Capable of Smart Energy 1.x and Smart Energy 2.0 v1.0 through Application Layer Gateway
- On the fly configurable as a Bridge, Application Layer Gateway or a Router

POWER

- 6 to 60V @5W DC bus or 100-277VAC.

PHYSICAL

- 6inch x 6inch board. The board can be mounted in a ruggedized IP68 enclosure at factory if needed.
- Weight: 280g
- External antenna connectors are SMA - male

The MPR4D was meant to aide in the research of the Internet of Things (IoT) and connected devices in the home as seen from the features. A variety of standard and proprietary options for home networks including Wireless connectivity technologies such as ZigBee, Z-Wave, and others in the consumer market may be explored with this device. For these technologies to connect to cloud services on the Internet, the MPR4D may be employed as a “hub” or “gateway” device.

The MPR4D VLANs permit the utility to connect securely to the devices it has interest in while allowing the customer to establish a separate VLAN for home use without affecting the security or connectivity of the utility VLAN. Using a dual SSID capable device removes the constraint of requiring the customer to buy an additional router to connect utility smart devices to the Internet.

In this device, connected devices could default to cellular connectivity to the internet in those cases where the wired cable connectivity to the home is out.

The Wi-Fi Persistent Connectivity MPR4D platform addresses many future issues through the addition of functionality in the router.

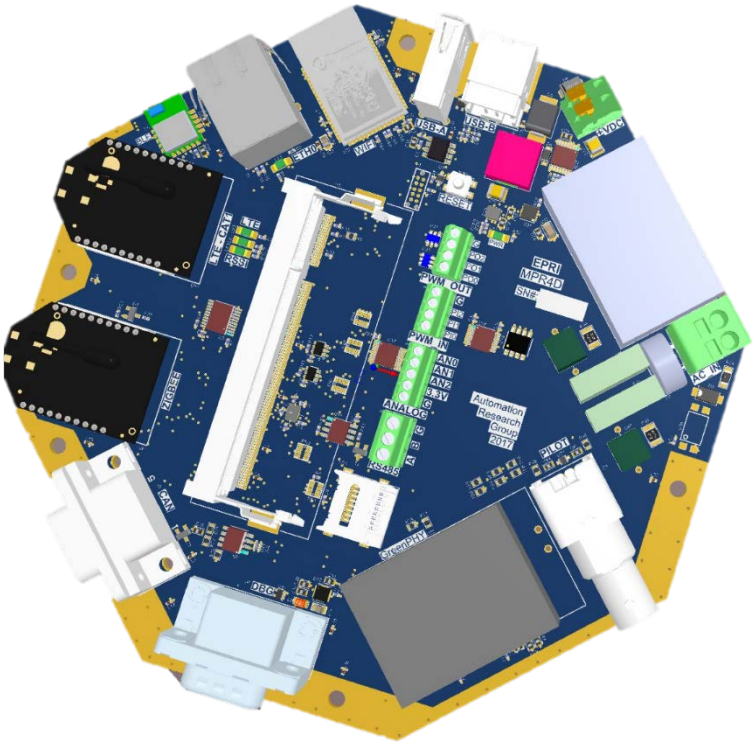


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Figure 2-1
MPR4D Multi-Protocol Router

Section 3: Commercial Off-the-Shelf Routers

The minimum requirements for the commercial off the shelf routers are met by most modern high performance Wi-Fi routers. Minimally 2 SSIDs, a fast processor, and large memory permit the implementation of a Wi-Fi Network and secure tunnel provisioning mechanism to establish a persistent and secure connection between devices at the customer and the utility they connect to, using the customer's Internet connection.

The Wi-Fi Persistent Connectivity Platform adds functionality to the router to create a persistent, secure network for connected devices. A typical consumer Wi-Fi router is shown in Figure 3-1.

Figure 3-1
Commercial Wi-Fi Router

The Wi-Fi Persistent Connectivity Platform adds functionality to the router. The added functionality is software only; no hardware changes are necessary. The added software is relatively small and is straightforward to add to the typical Linux-based router. Requirements specifically are:

- A secondary Service Set IDentifier (SSID)[1] on the Wi-Fi network – also called a Virtual Access Point or VAP. It is Virtual because it is in addition to the normal SSID of the primary network, and shares the same radio interface.
- A Virtual Local Area Network (VLAN) internal to the router, which isolates network traffic from the Virtual SSID.
- A Virtual Private Network (VPN) connecting the devices on the Virtual AP VLAN to the service provider. This VPN connects over the router's Wide Area Network (WAN) interface, establishing a secure tunnel over the Internet.
- A Service Provisioning API. This standardized API enables the provisioning server to configure the Virtual SSID, VLAN, and VPN, based on security credentials and provisioning information provided from the utility or service provider.

[1] Service Set IDentifier – the network name used to identify a Wi-Fi Network.

Section 4: Operation and Test Results

Both Wi-Fi routers were re-flashed with the OpenWRT Linux kernel Operating System. EPRI developed code extensions were added and additional security features added. The added code permitted the establishment of the required SSID setup and secure tunnel. Both devices were tested using Wi-Fi enabled Lifx LED lights.

Both devices have re-connected to the devices after storm power outages and both routers have not shown any performance degradation when performing the normal Wi-Fi router functions. These have been installed and have been running continuously for more than 6 months. As a by-product, certain issues with specific Wi-Fi attacks can be mitigated by using this technique. Secure trust servers may be placed to provide additional authentication for secure tunneling in the router.

Testing continues and more devices are planned to join the trials. These include water heater modules, load switches, and other generic load devices with the CTA-2045 interface. EPRI will continue to work with other vendors as the technology gains acceptance for certain third-party devices with their own dedicated server/interface to load switches, thermostats, AC controllers, circuit breakers and the like.

Section 5: Next Steps

The prototype technology will be further tested in the follow-on project, the Persistent Wi-Fi Demonstration Project. This project will conduct field demonstrations of the technology with use cases and devices selected by the participating members. In addition to providing connectivity for the devices, the demonstration will gather metrics on the connection and performance. This quantitative data will substantiate the improvement in connection persistence, and provide deeper insights into the root causes of connectivity losses.

The EPRI is leading an effort to establish standardization of the technology within the Wi-Fi Alliance. The goal is to enable built-in support for a secure persistent Wi-Fi network in commercial gateways and routers provided by Internet Service Providers as well as those sold in retail. Standardization and widespread adoption of this approach for connected devices in general is expected to reduce cost for deployment. Customer-connected devices will be able to take advantage of Persistent Wi-Fi without having to deploy a router or other hardware with the connected device.

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