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## **Residential Autonomous Fire Fighting Robot**

### **Networking Hardware and Wireless Communication in Smart Home Smoke Detectors**

#### **Introduction**

The advent of the Internet of Things (IoT) has brought widespread interaction and data exchange between networks of connected devices. Many in-home devices that have existed for decades are now being connected to the internet, giving users precise control and greater feedback. Smoke detectors are one such device that can now wirelessly communicate with users and emergency services with detailed alerts. They can even control other connected devices in real time, such as shutting off a ventilation system to slow the spread of smoke [1]. This paper reviews the underlying hardware and communication protocols used in networked smoke detectors, then looks at top of the line commercially available models, comparing functionality against connectionless devices.

#### **Logical and Networking Hardware**

Wi-Fi has become a widely adapted service in homes and businesses across the world. This universality has made Wi-Fi a premier choice for adding connectivity to other devices and appliances [1]. There are several additional requirements for IoT hardware that is unique from devices such as phones and computers. IoT devices are required to function in low power and network bandwidth environments [2]. The Internet Engineering Task Force (IETF) and IEEE Standards Association (IEEE-SA) have developed a set of requirements for IoT devices to ensure widespread reliability and compatibility of a growing number of connected devices [1]. Another key concept of IoT is the idea of a network of sensors [2]. A smoke detector must have hardware that has the capability of running logic to decode sensor data and transmit the results over the network. Lastly, a unique requirement of smoke alarms is the ability to function reliably in a harsh temperature environment [2].

The Espressif ESP32 is an example of a widely used Wi-Fi micro-controller board that meets the logical, networking, power, and reliability requirements for an IoT smoke detector [3]. This is a low-cost solution at \$8.55 from Adafruit [3]. The ESP32 has several methods for creating efficient, low power consumption, such as dynamic power scaling and the ability to wake up only when a condition is met [4]. Power consumption ranges from as low as 0.5 mA during a light sleep mode, to 200 mA when fully powered and transmitting Wi-Fi [4]. This chip supports Wi-Fi protocols 802.11 b/g/n/e/I, with the 802.11 n rated for 150 Mbps at 2.4 GHz [4].

## **Communication Protocols**

IoT smoke detectors must communicate with other digital devices in a low-power, low-bandwidth environment. Additionally, low on-chip storage requires a lightweight protocol with little code overhead [3]. Message Queue Telemetry Transport (MQTT) is a popular messaging protocol with a publish/subscribe architecture. In MQTT, there is a broker that acts as a central communication point between multiple devices [5]. Devices can publish data to the broker, and they may subscribe, or read, data from the broker. This indirect form of communication allows the smoke detector to sleep when it doesn't actively need to publish data from a sensor [2]. MQTT maintains basic application layer security features, such as only allowing devices with a specific client ID to publish or subscribe [5].

## **Commercially Available Wi-Fi Enabled Smoke Detectors**

The Nest Protect is the highest rated smart smoke detector according to [6]. The Nest Protect is sold for \$119.00 [7] and has competitors such as the Amazon Alexa smoke detector at \$199.00 and the Kidde model at \$49.97 [6]. The Nest Protect supports 802.11 b/g/n Wi-Fi connections and is Bluetooth enabled [8]. The micro-controller reads inputs from several sensors, such as heat sensor  $\pm 1.8^{\circ}\text{F}$  ( $\pm 1^{\circ}\text{C}$ ), humidity sensor  $\pm 3\%\text{RH}$ , and an occupancy sensor with  $120^{\circ}$  field of view [8]. It can operate between  $40^{\circ}\text{F}$  and  $100^{\circ}\text{F}$  and has options of running off of 6 AA batteries or 120V wired connection [8]. A unique feature of the Nest Protect is its ability to interface with other Nest products. In the event of an emergency, it can turn on lights for safety and activate/deactivate the home heating and air conditioning system based on the type of emergency [6]. The Nest devices come with access to a mobile application, giving real time feedback and control of the system [8].

The invention of IoT smoke detectors has increased the effectiveness of the security device in several ways. The ability to transmit sensor data to a central processing hub allows for more detailed analysis of a combination of data from multiple sensors, giving less false alarms and more accurate descriptions of the type of emergency. The system is also directly connected to emergency services, allowing for accurate sensing when nobody is present to call in the emergency [9].

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