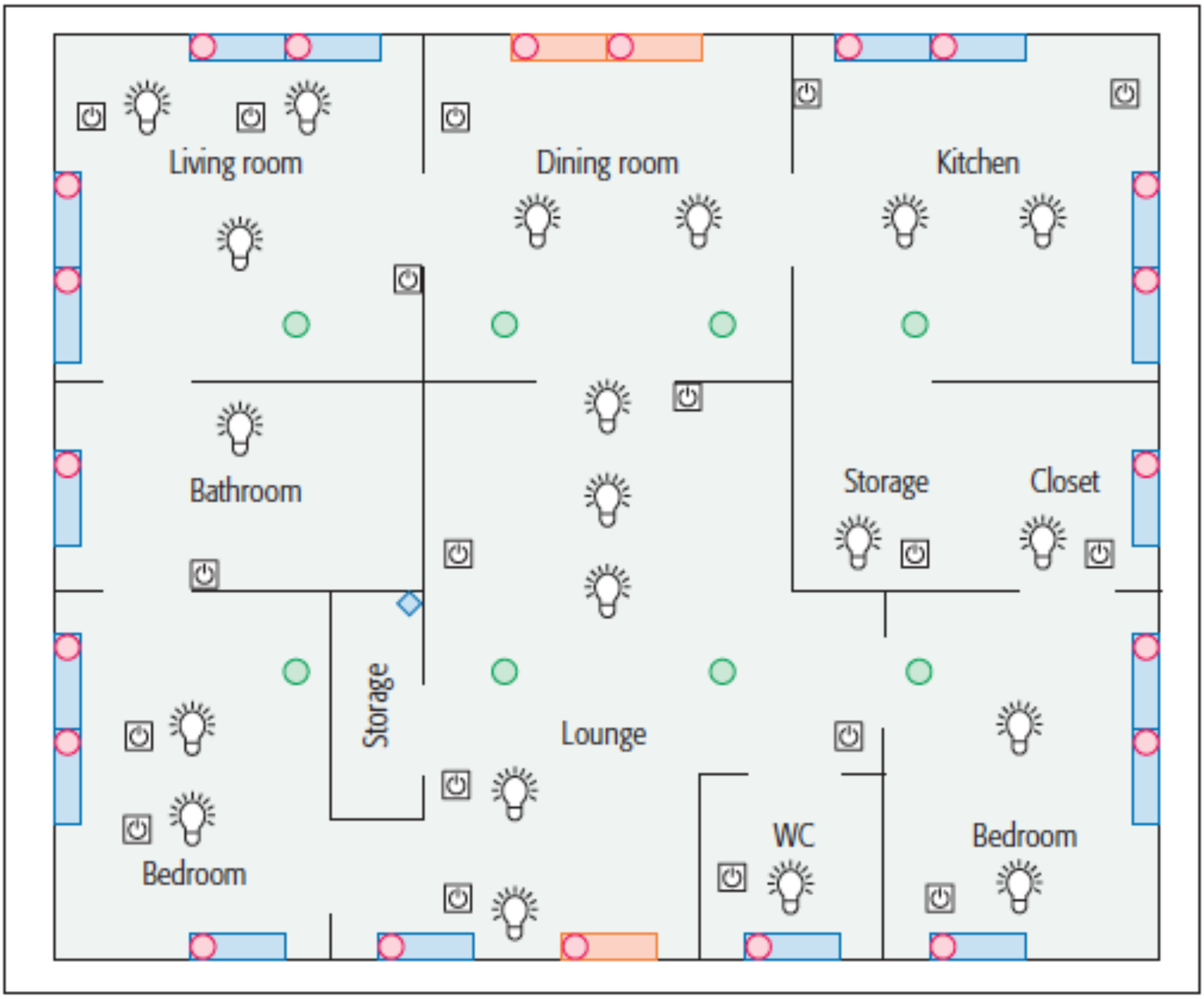
Simulation Scenario (Home Automation)



The considered scenario consists of a single-family home surrounded by a yard. The home, depicted in the above figure, comprises a single floor and measures 12 m x 10 m. Sensor and actuator devices are deployed within and just outside the building. The devices include window and temperature sensors, asset tags, and light switches and light bulbs. In total, 77 devices are deployed, including the central gateway that acts as a central device. The characteristics of the different device types are as follows:

- The central gateway is mains powered having its radio receiver always active. It implements the application logic, for example a local cloud, and it has Internet connectivity for messages directed to an external cloud.
- The sensor devices are battery powered and are typically in sleep mode with their transceiver turned off. When a sensor report is generated, the radio components are activated and the communication process starts. To keep energy consumption down, sensor devices are not reachable by the central gateway except when a new sensor report triggers the devices to become active.
- Actuator devices are waiting for application-layer actuation commands to act upon, meaning that they must be reachable by the central gateway.

Radio propagation

Radio propagation is modeled using the indoor propagation model from [1], which assumes 6 dB internal wall loss and a distance-dependent propagation loss of 0.5 dB per meter. Shadow fading is assumed to be uncorrelated across links and is modeled as a log-normal, distributed random variable with zero mean and a standard deviation of 6 dB. The central gateway antenna gain is 0 dB while the sensor and actuator antenna gains are–4 dB. For a receiver that is turned on and tuned to the correct channel, the packet reception probability is determined by the signal-to-noise-and-interference power ratio (SINR) at the receiver, as well as the physical layer performance of the modulation and coding scheme used [2].

Traffic Models

Two types of application layer messages are modeled: a sensor report and an actuation command. A sensor report message is generated by a measurement of a physical property or a change of physical state. For instance, a sensor report can communicate the change of the state of a light switch, location data, or temperature measurement. For security applications, sensor reports can be sent independently of a change of state to confirm that a device is still functional, such that the absence of these messages can determine that the node has stopped working. An actuation command message is generated by the central gateway's logic in response to a sensor report. The only actuation command modeled is triggered after a light switch sensor report is received from a sensor device.

Application-layer messages are randomly generated with an inter-arrival time that is exponentially distributed. There are 21 window security sensors sending data or presence messages every 5 s; there are eight temperature sensors sending data every 60 s, and there are 10 asset tags sending data or presence messages every 1 s. Furthermore, there are 18 light switches that communicate with 20 light bulbs every five minutes.

Window sensors, temperature sensors and asset tags report data to the Internet via the central gateway, while within the same network light switches communicate with light bulbs. A command from a light switch is first transmitted to the central gateway, in which it is processed on the application layer, resulting in a command from the central device to one or several associated light bulbs. Accordingly, in this setup all data transfer takes place via the central gateway and there is no direct communication between sensors and actuators.

The link layer payload associated to each sensor report and actuator command is assumed to be 251 bytes long. The application-layer model is very simple and no specific higher-layer protocols are modeled.

Performance Metrics

The comparison is based on a set of key performance indicators which are defined as follows.

Service ratio: Generated traffic is created by devices in the network, whereas served traffic, or throughput, is the traffic being successfully delivered to intended destinations. Both include uplink and downlink traffic. The service ratio is defined as the quotient between served and generated traffic and the traffic loss ratio is the complement of the service ratio.

Packet delay(s): The packet delay is measured for application-layer messages only. It includes the time from sensor report generation to actuator message reception and is only relevant to measure for light bulbs. Processing time is assumed to be negligible in this setup.

Battery lifetime: The battery lifetime is the expected time that a battery-powered device can operate before the battery becomes empty. The battery lifetime is calculated starting from a 220 mAh battery capacity, by combining the time spent in each state and the current consumption in active state(s) and idle state.

[1] C. Tornevik et al., "Propagation Models, Cell Planning and Channel Allocation for Indoor Applications of Cellular Systems," IEEE Vehic. Tech. Conf., 1993.
[2] K. Murota and K. Hirade, "GMSK Modulation for Digital Mobile Radio Telephony," IEEE Trans. Commun., vol. 29, no. 7, 1981, pp. 1044–1050.