SensArray Power Distribution

Introduction

A central design feature of the SensArray is its ability to support power distribution. This note focuses on power distribution using a network of SensArray units. We start with an idealized discussion and gradually add in real-world effects. Finally, we show practical methods for powering a network of units.

A central feature of this discussion is providing the user with easily implemented options to eliminate any need for 120V conduit or extension cords.

SensThys has tested multiple PoE injectors and DC supplies. This work has shown substantial variation in the robustness of power supplies – leading to SensThys strongly recommending using either the SensThys injector or the SensThys DC supply where possible. Even though our products will "handshake" with any standard PoE injector or PoE switch. we have found that some other injectors or PoE switches may not provide adequate power for many applications. In an under-powered system, parts of your network may not power up. Other parts may become power starved when various loads are turned on and quite probably power cycle.

SensThys recommends copper-based Cat 5, Cat 6 or Cat 7 cabling.

An Idealized PoE Network

We will start with the simplest networking configuration, a linear string of units. This is often referred to as "daisy-chaining".

PoE+ can provide 26W-30W of power depending upon the exact specifications of the PoE+ power source. PoE+ provides power sequentially as shown in Figure 1. In the upper left, PoE+ is introduced to device N1. After a handshaking process, device N1 turns on and offers power to N2. Following the completion of the handshake between N1 and N2, power is offered to N3. This process will continue until the power consumed after the last device results in a condition where the total power consumed is greater than the PoE+ system can provide.

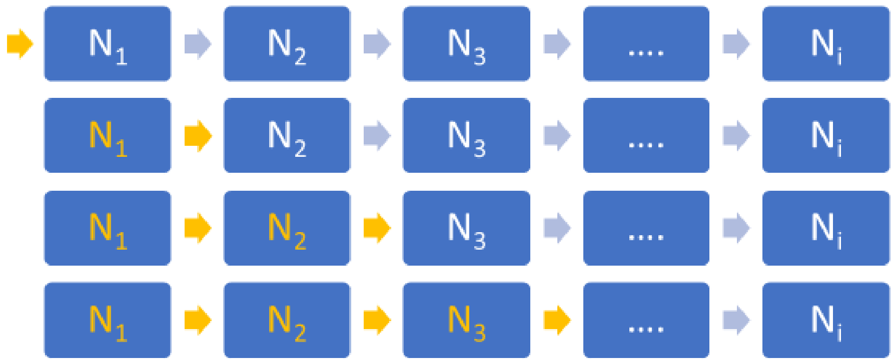

Figure 1 Showing the process that PoE uses to power a string of devices.

If all the units connected to the PoE+ supply have identical power consumption, then the total power consumed is the power consumed per device times the number of devices in the string.

*Total Power = Power per Unit * Number of Units*

This can be easily rearranged to give the maximum number of units that a single PoE+ power supply can provide.

Number of Units = Integer (Total Power Available / Power per Unit)

Figure 2 shows how the number of supported devices changes with the power required per unit.

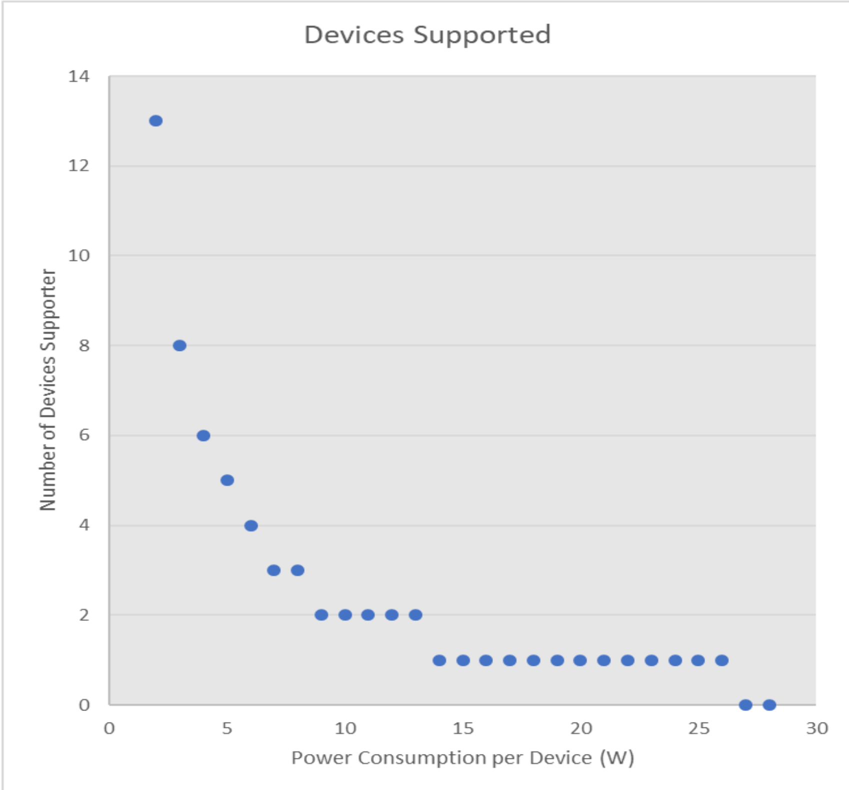

Figure 2 The number of devices supported by a single PoE+ supply. As the power consumed per device decreases, the number of devices supported increases.

Simultaneous Operation of Multiple SensArray+

The SensArray+, in idle, consumes about 3W of power. Thus, we see from Figure 2 that a PoE+ supply can support 8 SensArray+ devices . . . right? Well, no.

The SensArray+ has two basic modes of operation. The first is when it is in idle. The functions performed in idle include PoE+ power distribution and Ethernet switching, but the RFID reader is not operational, the GPIO is resting and no additional PoE devices are attached. So, it doesn't take much power, but it also doesn't do a whole lot in idle. The power consumed by the SensArray+ in RFID read mode varies by power and RFID mode to a maximum power consumption of 9W. Thus, Figure 2 shows us that the maximum string length for SensArray+ decreases to 2 devices when both of their RFID readers are on at the same time. Specifically, two SensArray device can be powered from a single PoE injector if both units are operating at an output power of 30 dBm.

Key Point

For SensArray+ applications where units might be on simultaneously, the maximum number of units operating off a single PoE+ supply is 2.

Next, we'll discuss the specifics of how to connect SensArray or SensArray+ units. The SensArray has two RJ45 Ethernet ports, Port 0 and Port 1. The SensArray+ has three, Port 0, Port 1, and Port 2. The following discussions only use Ports 0 and 1. If more than two units are needed in an application where all the units must simultaneously be in operation, additional power can be conveniently connected to the chain as shown in Figure 3. In Figure 3, yellow arrows indicate power is being supplied, grey arrows show a data connection only.

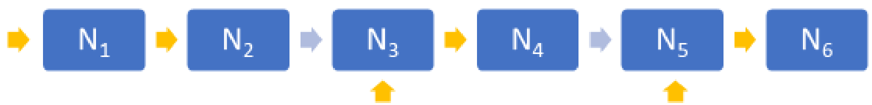

Figure 3 Six units connected in series. Units N1, N3 and N5 power N2, N4 and N6, respectively. PoE+ injectors are connected to Ethernet Port 0 on N1, N3 and N5.

Here are the instructions for wiring the SensArray+ in this configuration. Power and data from a PoE+ server are provided to N1 by connecting the Ethernet cable to Port 0. N1 Port 1 is connected to N2 Port 0. N2 Port 1 is connected to N3 Port 1 to transmit data between N1 and N2, and back to the server. A remote PoE+ power injector, which simply plugs into a convenient existing 120VAC outlet, is connected via Ethernet cabling to N3 Port 0. The connections between N3 and N4, and N5 and N6, mirror the connections between N1 and N2. Finally, power is supplied to N5 Port 0 via a remote PoE+ power injector.

The SensArray+ can also be powered by the SensThys DC supply. This supply can power one more unit in the string, so the string of six units in Figure 3 requires only 2 DC supplies as shown in Figure 4.

Key Point

The DC supply increases the number of allowed units in a string by one.

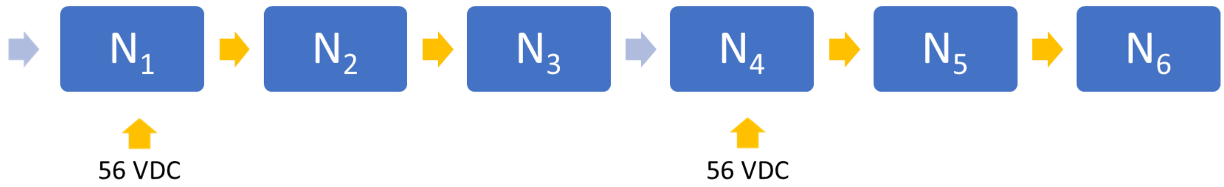

Figure 4 Six units connected in series with power being supplied via two 56VDC supplies. This configuration can support simultaneous operation of all units.

Here are the instructions for this configuration. The server should be connected to N1 Port 0 (N1P0). Power is brought to N1 via the DC input. Using our abbreviation, N1P1→N2P0, N2P1→N3P0, N3P1→N4P1, N4P2→N5P0 and N5P1→N6P0.

SensArray Networks Without Simultaneous Operation

In some RFID configurations, the "on" time of any reader is small. In such a configuration, a network of units can be configured so that only one reader is operating at a time. Since the operating power of the SensArray+ while reading is ~9W, that leaves ~17W of power for the additional units, suggesting that an additional five units could be connected. In practice, the SensArray+ (and base model SensArray) briefly consume more power than 9W when the RFID reader is turned on, thus we recommend the total number of units operating be limited to 4 when operating off a single PoE+ power injector or 5 when powered off the SensThys DC supply. These configurations are shown in Figure 5.

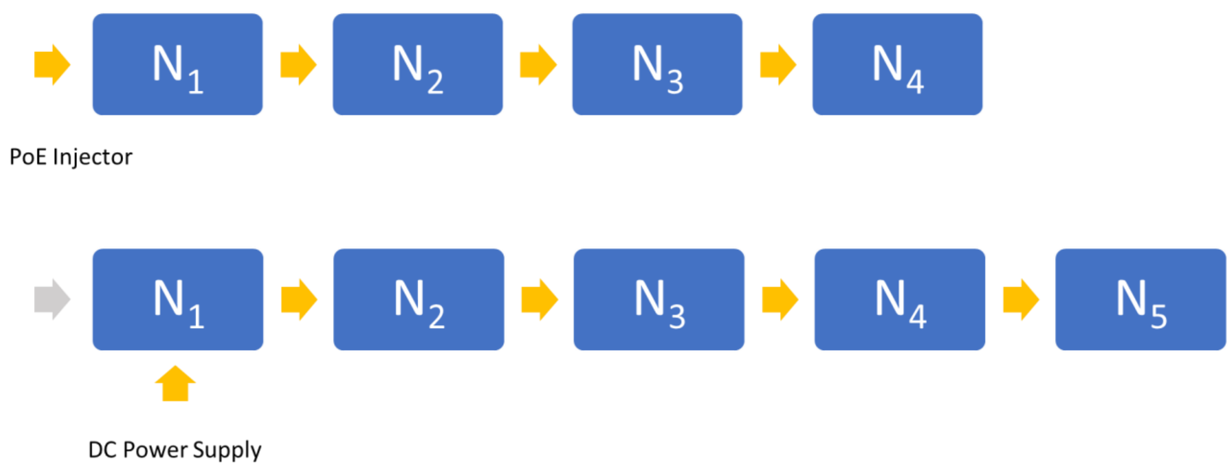

Figure 5 Two Configurations for linear networks where a single unit is powered for RFID operation at any given time. The upper diagram shows N1 powered by the SensThys injector, with the lower diagram shows the string of units powered by the SensThys DC supply.

With the PoE injector, the connections are as follows;

Injector → N1P0, N1P1→ N2P0, N2P1 → N3P0, N3P1 → N4P0

With the DC power supply, the connections are as follows;

Computer or server (non-PoE) → N1P0, N1P1→ N2P0, N2P1 → N3P0, N3P1 → N4P0, N4P1 → N5P0

If constructed with SensArray+ units, these configurations have many open PoE power sourcing ports open. Specifically, P2 is open to communicate with other Ethernet devices or even power PoE devices like a camera or phone.

Powering Complex Networks

The SensArray+ has three ports and provides additional options for data and power networking.

Let's start by simply taking a single Ethernet line from the IT closet and fanning it out using the SensArray+ architecture. In Fig. 6 seven units are linked to a single line coming from the IT closet. Totally excellent, we only have to work with the IT guy once! The wiring configuration for that is:

Ethernet line to AP0, AP1→A1P0, AP2 → A2P0, A1P1 → A11P0, A1P2 → A12P0, A2P1 → A21P0, A2P2 → A22P0. Whew!

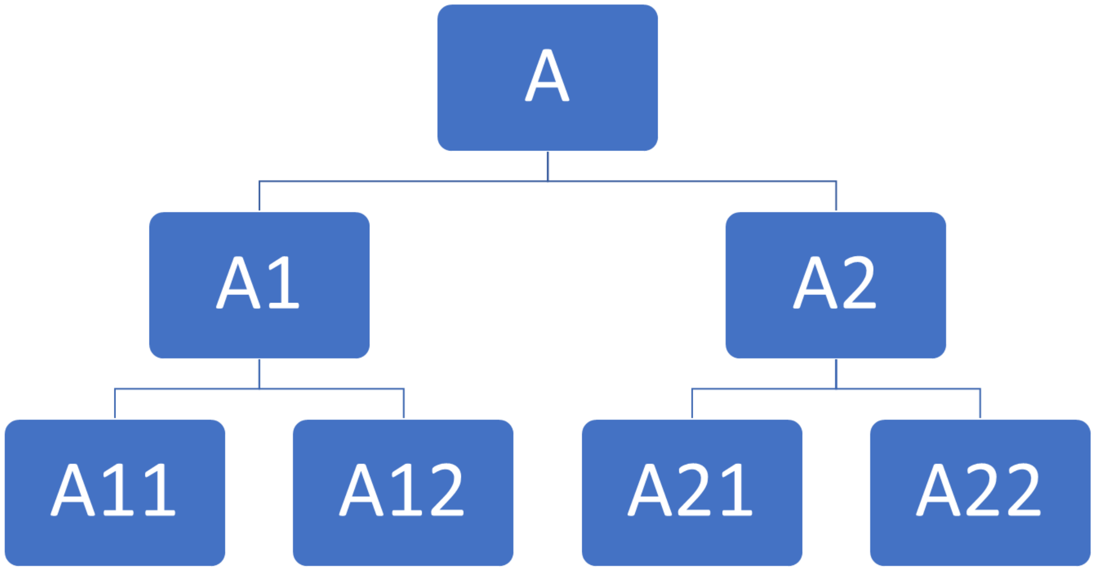

Figure 6 Seven SensArray+ units connected to a single Ethernet line.

The casual reader says, big deal, org structure with span of control = 2. Fair point. The real reason for showing this embodiment is to get at the question of how complex networks can be powered.

To get at this, let's just write down some simple rules that can guide the system designer.

First, there are some simple restrictions on how your system can be wired.

Wiring Rules:

1. Power can only be delivered to Port 0
2. Power can only be delivered from Port 1 and Port 2 (SensArray+)
3. The injector can be placed up to 100m away from the unit, i.e., the 120V outlet supplying power to the injector can be a long way from the unit
4. The DC supply must be within ~2m of the unit

The first two wiring rules are restrictions derived from the SensArray and SensArray+ hardware. Rules 3 and 4 need to be considered when providing auxiliary power since the choice of how to supply that power depends on where 120VAC power is available and which units in your SensArray network need the power. If you have a nearby outlet, you can use the SensThys DC power supply. If power isn't close by, you may need to run PoE power from an injector set up close to a 120VAC plug.

The following rules are used to help sort out your power budget and where to provide supplemental power if you find devices within your network are over the available power.

Power Budget Rules:

1. The power consumed by a unit is ~ 3W, if the unit is idle, ~9W, if the unit is operating at P_{out} = 30 dBm.
2. The SensThys Power Injector can provide 29W.
3. The SensThys DC supply can provide 75W.
4. Port 1 and Port 2
    a. can deliver up to 27W each,
    b. but can only deliver up to the power into the unit less the unit consumption
5. A 5W buffer is recommended at each power distributing unit

Ok, we've got good rules, let's apply the power budget rules to the configuration in Figure 6. We start by inserting an injector between the server and A.

The power delivered to A is 29W. Let's assume that A, A1 and A2 need to simultaneously operate, making power consumed = 3 x 9W = 27W. Adding the 5 W buffer gives us 32W— so this configuration doesn't work.

This can be solved in a couple of ways. The first is to power A with the DC supply, which can deliver 75W of power. The second is to insert an additional injector between either A and A1 or A and A2. Another alternative would be powering either A1 or A2 with a DC supply.

Similar thinking must go into the question of how to power A11, A12, A21 and A22, but the calculations remain based upon the rules outlined above.

As an example, let's assume that we connected a DC supply to A. If we subtract the 5W buffer and assume that we will be operating the radio, we have 75W – 5W – 9W = 61W available to deliver from both ports 1 and 2. This is more than enough power for units A1 and A2 since ports 1 and 2 can deliver at most 27W each, or 54W total. Now if we look farther down the chain, we find that if we want A1, A11, and A22 to operate simultaneously we have a power budget for A1 of 3 x 9W + 5W (buffer) = 32W. So just as in the example earlier, we will need to insert an injector between A1 and A11 or between A1 and A12 or provide a DC supply to power any of A1, A11 and/or A12. A similar calculation needs to be done for A2, A21, and A22.

Powering PoE or GPIO Accessories

So far, we've discussed a very specific set of cases – using a SensArray or SensArray+ to power another SensArray or SensArray+. These units were designed to provide much more in terms of flexibility and connectivity.

GPIO Accessories

The SensArray+ has a GPIO connector with 4 outputs, as well as 24VDC that can be supplied through another pair of connections with a total supply capacity of 600mA at 24V, or about 14 watts. GPIO accessories can include lighting, light stacks, motion-detecting switches, etc.

The power consumption by GPIO accessories should be included in the total energy budgeting, as this power must be supplied either by the PoE system or a DC supply.

PoE Accessories

The SensArray units can drive PoE compatible accessories, such as cameras, lighting, and even phones. The power consumption of PoE accessories should be included in the total energy budgeting, as this power is supplied either by the PoE system or a DC supply.

Example: Let's consider the example shown in Figure 7. In this case, we have two units connected to each other in a daisy-chain with a light stack powered through the GPIO connector and a PoE camera connected to each unit through PoE port 2.

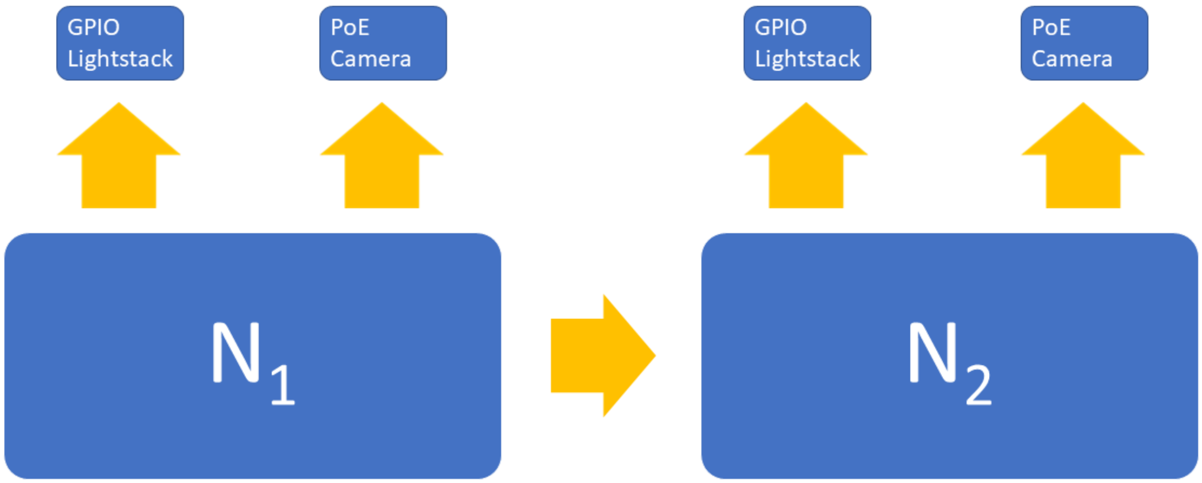

Figure 7 Two SensArray+'s each with a light stack and a PoE camera.

Let's assume that our light stacks consume ¾W when powered, and our PoE cameras consume 4W each when running. In this case, our power requirements are (9W + ¾W + 4W) x 2 + 5W (buffer) = 32 ½ W. This is clearly over the 29W power level that can be supplied by the PoE injector. As with our previous examples, there are a few ways that we can solve this problem. The easiest would be to power unit N_1 using the SensThys' 56VDC power supply. If accessing nearby power is a problem, N_2 could be powered using a PoE injector. Another option would be to provide separate power for one of the PoE cameras leaving ½W to spare.

Key Point

The power budget can be assessed using a handful of simple rules applied to all the concurrent power loads in the SensArray network.

In Summary

Architecting a SensArray network that effectively takes advantage of the different ways of delivering power to the various devices throughout the system requires some analysis. Generally, however, there are only a couple of basic considerations: how close are each of your units to available power, and how much power does each unit need to deliver to attached devices.

As discussed in the section "Powering Complex Systems", we saw that the power consumption through your network can be analyzed using 5 easily understood rules. Once you find a power deficit in your system, it can be mitigated by providing supplemental power to SensArray units through either a PoE injector or an auxiliary DC power supply.

With a bit of analysis and attention to the rules spelled out above, you will be able to design a robust network or SensArray and SensArray+ units driving auxiliary devices. You will be able to do this without the expense of running electrical conduit and multiple runs of PoE wiring from your IT closet.