White Paper
Single Pair Ethernet (SPE)

This whitepaper is going to discuss the phenomenon that is gaining a great deal of column inches now. We will be looking at the drivers behind it and where it has come from, along with the target markets and market potential.

We will then look at the latest standards developments underway that will make this technology the basis for a huge potential market sector that structured cabling has been struggling to dominate for a number of years.

We will then look at what it physically is and how quickly it will become a standard product set that we deal with on a day to day basis.

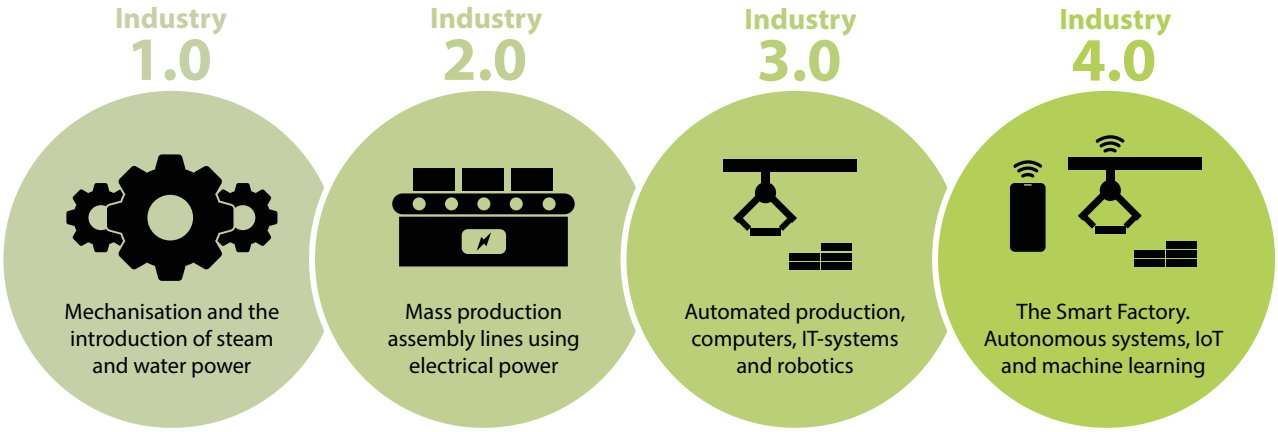
Where has it come from?

In 2016 the IEEE put together an 802.3 working group to discuss a call for interest in 10Mb Single Twisted Pair Ethernet. The initial meeting predominately included companies from Industrial Automation and Automotive companies. The intention was to explore the market needs and solution requirements along with the target markets and their size and potential before looking at the technical feasibility of a solution.

Industrial Automation was the first sector explored. This interest can be explained in three ways:

- Desire to converge under one network protocol
- Ethernet adoption is/was already happening where possible
- Non-Ethernet Fieldbus was still required to complete communications to the edge in some cases.
    - The challenges to overcoming this were:
        - Cable lengths over 1Km
        - Very low bandwidth ≤1Mbs

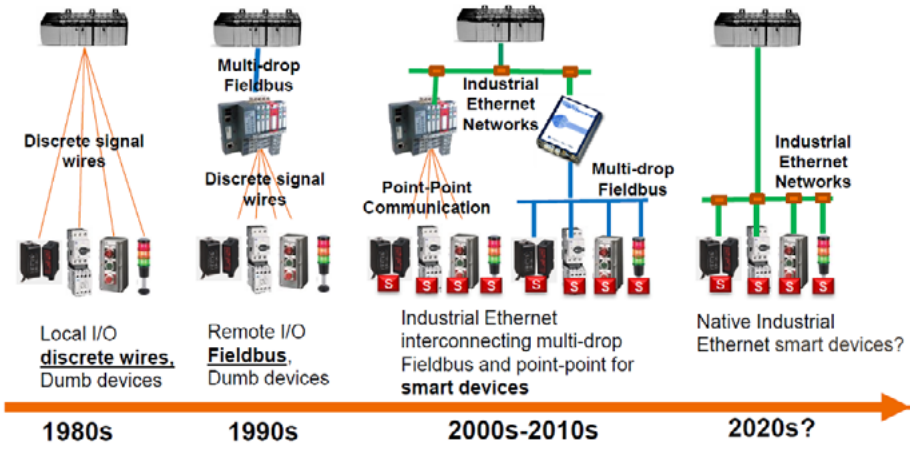
The last item is complicated by the number of Fieldbus options available each of which create maintenance and installation issues that it is desirable to avoid for Opex reasons if possible.
With the emergence of Industry 4.0 it will require higher data rates at the edge, higher speed data logging, environment states and energy consumption, along with the optimization of both equipment and maintenance data.



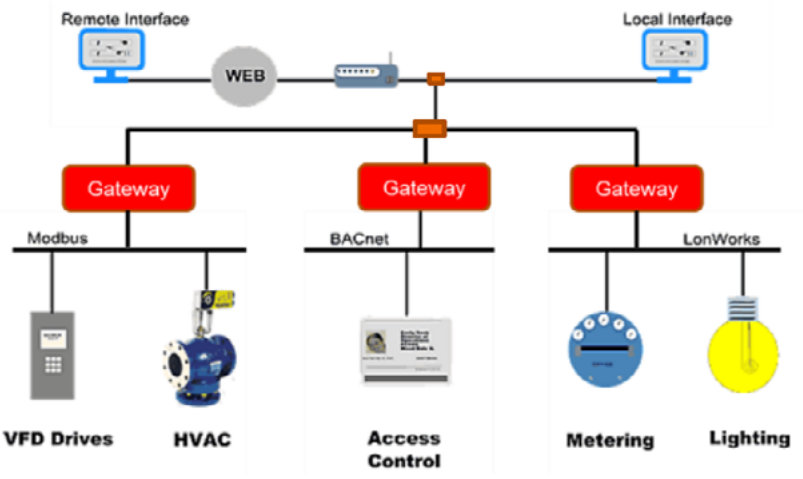
The Automotive Sector is also fully behind 10Mbs Single Twisted Pair Ethernet, in fact it could be claimed they are ahead of the curve with 9 organisations operating in this sector being represented at the initial meeting some with multiple delegates, including BMW, Toyota, Nissan and Renault to name just 4.
With the increasing complexity of the electronics within vehicles with more ECUs and sensors, there are clear advantages for overarching IP communications.

What is behind the drive behind the adoption of SPE?

The justification for ethernet to the edge in Industrial Automation is that it will lead to a single network protocol and remove the need for the complex gateways needed to convert from multiple different Fieldbus protocols such as MODbus, HART and Interbus etc. This in turn will lead to more rapid commissioning and fault diagnosis and repair. All of the above together with the greater economies of scale by its adoption will result in lower total cost of ownership (TCO) and a better Return on Investment (ROI).



10Mbs Single Twisted Pair Ethernet addresses most Fieldbus applications up to 1200m. Furthermore, many devices require power, and this can also be easily covered by the currently proposed cables the majority of which will be based on a larger conductor size of between 18-24AWG dependent upon distance, and primarily of a screened construction.
Building Automation, whilst not part of the original call for Interest has a very similar set of issues and requirements, there is already a transition underway with things like BACnet IP however there is also a great desire to converge on one network type and move away from in some cases proprietary protocols.



Adapted from: Carlson/Kennedy, IEEE 802 BoF "I Feel the Need… for Low Speed", July 2014

As far as the Automotive sector is concerned many legacy in-vehicle networks (IVNs) utilise lower data rates than those proposed for SPE, therefore transition from legacy IVNs to ethernet requires not only lower cost but also lower power potentially reducing emissions and solving multiple issues within this sector.

The transition to ethernet is well underway with:

- 802.3bp -2016 – Gigabit Ethernet over single twisted pair, automotive and transport environments.
  - 15m Automotive
  - 40m Aircraft, Railways, Bus & Truck
- 802.3bw -2015 – 100Mb ethernet over single twisted pair, automotive environments
  - 15m Automotive

There is now a clear drive towards 'Ubiquitous IP' to reduce the number of IVNs and multiple gateways.

Target Markets

The key markets for SPE is not to replace existing 4 pair networks but to run alongside it and exploit markets that have been seen as mainly out of reach of traditional structured cabling.

Industrial Automation

- Process Automation
- Factory Automation

Building Automation

- HVAC
- Security/Access Control
- Fire
- Lighting Control
- Residential

Automotive

- Pervasive IP Network
- Legacy IVN Consolidation

Market Potential

The Industrial Automation and Control market is undergoing significant growth in 2016 a report stated the traditional Fieldbus market was 58% of the total market and growing at 7% CAGR however, the Ethernet market was 38% but was set to grow at 20% CAGR. Based on a range of reports it was forecast that a total of 180m + ports would be supplied in 2020 (pre-COVID-19) 50% of which is addressable by SPE.

The Building Automation market size could be even more exciting with an IHS forecast again, in 2016 stating approx. 15 million controllers each with 2 ports would be supplied worldwide during 2020. On average each controller could interface to 10 sensors/actuators, which would result in 300 million connected devices (more detail of how this is achieved in the next section). With 10Mbs SPE being able to serve over 50% of this market.

The numbers quoted in the previous two examples could pale into insignificance when you look at the Automotive sector as there were approximately 4 billion IVN ports supplied in 2019. However, it must be noted that they will include higher bandwidth over very short distances and is more specialised than the main focus of this paper, which is to discuss the possible impact on the structured cabling market.

Taking the two key target markets of Industrial and Building automation as the focus the addressable sector for SPE could be in excess of 250m ports in 2021.

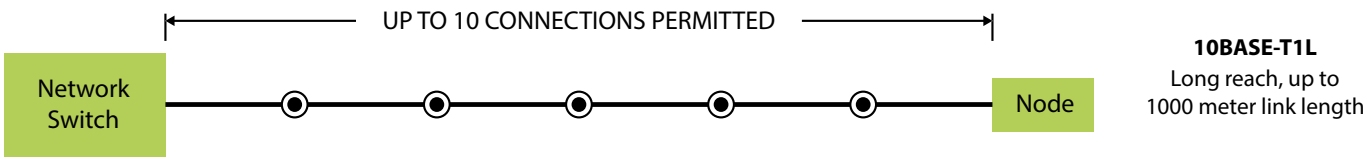
Exactly what is SPE? How it works and how it delivers power

IEEE 802.3bu:2016 – Power over Data Line (PoDL)

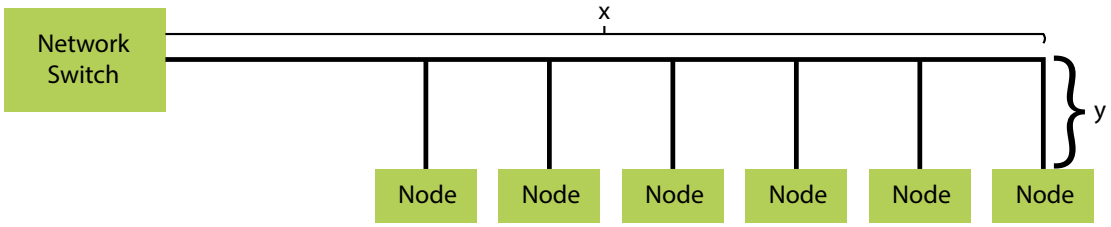
- Power delivery over single twisted-pair segment
- Pronounced “poodle”
- Sometimes referred to as SPoE (however it is technically different to PoE)
- Up to 52W of power, dependent upon cable, distance and number of connections

IEEE 802.3cg: 2019 – 10 Mb/s

- 10BASE-T1S – Link segment (point-to-point), 4 connections, 15m reach, PoDL power
- 10BASE-T1L – Link segment (point-to-point), 10 connections, 1000m reach, PoDL power



- 10BASE-T1S – Mixing segment (multidrop), 8 nodes, 25m reach



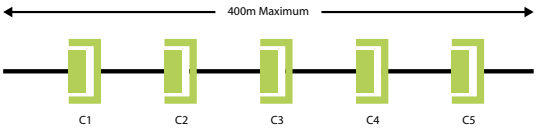
10BASE-T1S
Multidrop topology and up to 25 meter total length,
y + n(x) ≤ 25 meters

IEEE 802.3da – 10 Mb/s Multidrop Enhancements

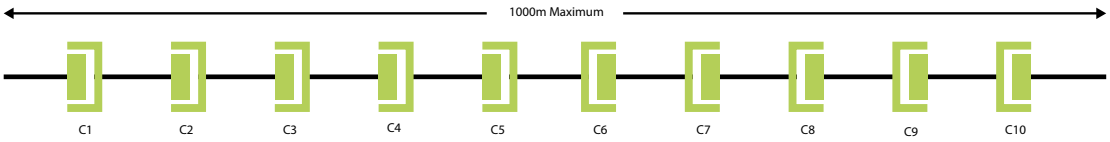
- Mixing segment (multidrop), 16 nodes, 50m reach, PoDL power

Channel Lengths

- SP1-400 Channel (23 AWG)



- SP1-1000 Channel (18 AWG)

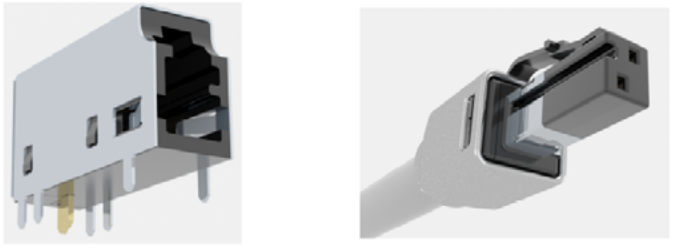


Connector Technology

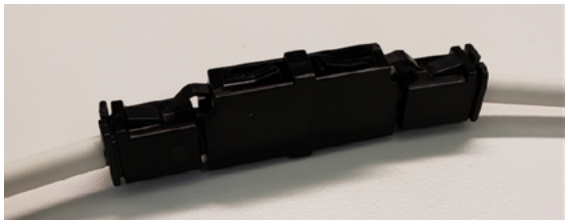
There are two basic groups of connector technology they are for use 'hardened' and 'non-hardened'.

IEC 63171-6
IP20 and IP67

Will typically be used in the Industrial Automation Sector.



IEC 63171 -1
IP20
Part of TIA 42.7
single pair specification



Based on the LC style foot print and will be predominantly used in the building automation and 'non-hardened environments.

Power Delivery

There are a number of factors that affect the power delivery distance and level of power, these are:

- Power class
- Conductor size
- Number of connections

There are 6 PoDL power classes for 10Mbs SPE applications, each class defines voltage(V), current(mA), power(W), and max DCR(Ω)*. The DCR value is used to calculate the theoretical maximum power delivery distance. Thankfully the IEEE standard 802.3cg provides a table that helps with this calculation.

Class	10	11	12	13	14	15
$V_{PSE(max)}$ (V)	30	30	30	58	58	58
$I_{PI(max)}$ (mA)	92	240	632	231	600	1579
$P_{PD(max)}$ (W)	1.23	3.2	8.4	7.7	20	52
DCR (Ω)	65	25	9.5	65	25	9.5

Source: IEEE Std 802.3cg-2019 Table 146B-1

*Resistance - $DCR_{loop} = DCR_{cable} + DCR_{cords} + DCR_{connections}$
This then allows the following distances to be calculated.

POWER CLASS 10 & 13 (1.23W / 7.7W)

AWG	No. of connections		
	2	5	10
18	1000	1000	1000
20	793	793	793
22	544	534	517
23	431	423	410
24	342	336	325
26	215	211	204

POWER CLASS 11 & 14 (3.2W / 20W)

AWG	No. of connections		
	2	5	10
18	519	494	451
20	326	310	283
22	205	195	178
23	163	155	141
24	129	123	112
26	81	77	70

POWER CLASS 12 & 15 (8.4W / 52W)

AWG	No. of connections		
	2	5	10
18	187	161	118
20	117	101	74
22	74	64	47
23	58	50	37
24	46	40	29
26	29	25	18

Maximum channel length determined by Insertion Loss limit
Channels that exceed 400m or have more than 5 connections do not comply with the SP1-400 channel topology requirements

Frequent Questions

Will SPE replace 4 pair Ethernet?

- SPE is not a replacement for 4 pair Ethernet IT Networks
- It is a totally new system to replace Fieldbus and other Automation based networks in the Industrial & Building Automation as well as the Automotive sectors
- The ability of 4 pair cable to support four SPE links simultaneously is still under evaluation

Can I buy SPE right now (2020)?

- The simple answer is no, there no systems commercially available at this time.
- Whilst the connecting hardware have been approved and the cables should be relatively straightforward, the PHYs (Physical Interfaces, Electronics) are still in development

Conclusions

There is a great deal of activity underway around Single Pair Ethernet with the IEEE and TIA at the forefront, however ISO/IEC are catching up fast, with the latter investigating the potential of the even more variants and distances including using 4 pair cable as a feed for multiple single pair drops.

Which ever way the level of interest across all the market sectors discussed is extremely high and not only are cable and connector manufacturers investing heavily the PHYs manufacturers are also pushing hard with announcements from the likes of Texas Instruments announcing that they have been able to drive SPE up to 1.5km whilst testing in their laboratory, nothing was mentioned regarding power so that may be a physical limitation they cannot overcome.

SPE is not going to replace traditional 4 pair structured cable in the Business IT sector but it will compliment it by merging the 'Experience Systems' used by Operational Technology on to a uniform communications platform.

As for timescales it is hard to predict, all the base standards are in place and the cabling could follow very quickly it is now case of equipment vendors coming up with the physical devices a lot of people are predicting that we will start to see systems rolled out in 2021.

If we then look at all the previous adoption curves for Ethernet technology, the time from early adopters to mass market is usually around 4 years, however in this case I believe that it will be accelerated by the predicted explosion in smart buildings and connected devices with one recent report stating this number will reach 75 billion within the next 6 years.

So, watch this space carefully. This technology is coming to a building near you in the not-too-distant future.

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