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Distributed AV Switching – A Game Changer

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This whitepaper starts with the traditional central AV switching system, and introduces the brand new revolutionary distributed AV switching, and compares it to the IT based desktop sharing and media streaming systems.

Signal switching and distribution is the heart of a pro AV system

Any AV systems consist three key components:

1) Source devices, like PC or MAC, DVD players, cameras, microphones, etc.
2) Display devices, like projectors, monitors and speakers, etc.
3) Switching and distribution devices, like switchers, splitters, matrix switchers, scalers, mixers, amplifiers and their control systems

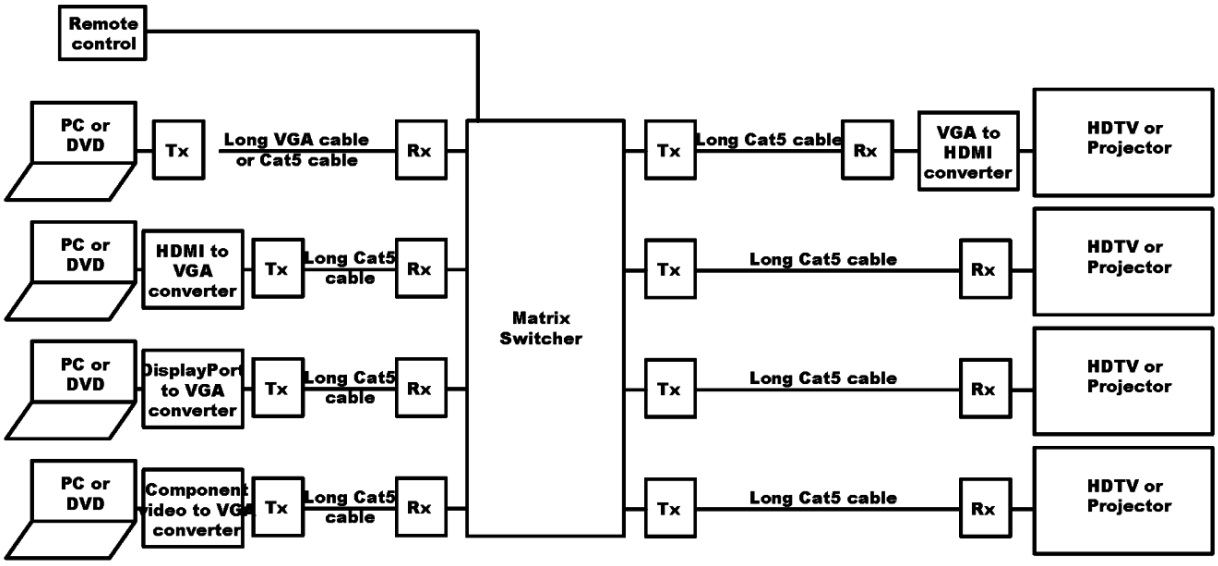
Most source and display devices are mass produced by few big manufacturers. The same PC can be used for virtually any system, big or small. The large volume and similarity among products result in small margin for manufacturers, installers and resellers.

On the other hand, the switching and distribution devices are often unique for each application; this leaves plenty of room for each manufacturer and each installer to utilize their unique skills and to make profit from. That's what the pro AV industry represented by Infocomm tradeshows is all about.

This article will concentrate on the switching and distribution devices.

Traditional central switching systems

For almost a century, the only way we knew for signal switching and distribution is to send all source signals to a central switching device (a big box), then distributing the signals from that central box to all the displays. In the IT world, this kind of system is called a star topology. Here's a representative diagram of this system:



These kinds of systems work well, especially for the small system with few I/Os (inputs and outputs). Without the alternatives, we have accepted this as the de facto standard even it has several major challenges:

1) **Cable installation challenge**: Because all source and display devices need to be connected to the central device, each input and output cable could be long and there will be A LOT of cables at the central box; see these familiar pictures here:



These cables often need to go inside the wall, over the ceiling or under the floor. At the user's end, it's even more difficult to hide these cables neatly. Imagine a conference table with 20 PC interfaces; there will be 20 thick VGA cables going from the table down to the floor; it's quite difficult for the installation.

2) **Cable length challenge:** Also because the star topology, each cable is often long in length. Think of a commercial building with devices in multiple rooms; the cable length to go from one floor or one side of the building to the other floor or side can be very long. This was already a challenge for the analog systems; a lot of expensive line drivers were made and used to address this problem. This is an even bigger challenge now with the digital systems. The digital signals are more difficult to go distance. Use HDMI as an example, most passive cables are only good for 20 m (60'); we just have a solution recently to send HDMI signal to 100 m (300') away with Tx (transmitter) and Rx (receiver) pairs; but the cost of each pair is close to $1000. The cost quickly adds up if more and more input and output cables in a system need these Tx and Rx boxes.

3) **Mixed signal format challenge**: We have the new digital signal formats like HDMI, HD-SDI, DisplayPort etc.; and plenty of legacy analog signal formats like VGA, component video or even composite video still widely in use. The central box can only switch and distribute one given signal format. So all the other source and display devices with different signal format than the central box must use scaler at each link to convert the signal to and from the system format. This is very expensive. The HDCP management makes it even more difficult.

4) **System upgrade or expansion challenge**: Once a system is installed, it's virtually impossible to add new input or output for expansion, or add new signal format hardware for upgrade. This is a major headache for the users and the installers; the technology changes every a few years and the system upgrade or expansion is inevitable.

5) **SKU and inventory management challenge**: This is not so much of a problem to the end users but it's a big headache for the manufacturers and the resellers. Because each central box has a fixed number of I/Os (inputs and outputs); the manufacturers need to make a 2 input and 1 output (short for 2x1), 4x1, 8x1, 16x1, etc. switchers, 1x2, 1x4, 1x8, etc. splitters, and 2x2, 8x4, 4x8, 64 x64 etc. matrix switchers to cover as many as possible applications. That results in hundreds of models (SKUs). On top of that, since each box can only handle one signal format, we need all those boxes in VGA, HDMI, DisplayPort, etc. signal formats in all those I/O sizes too. This pushes the total SKUs to well over 1000. Take a look a matrix selector screen shot from one manufacturer's website; the left one is the I/O size selector and the right one is the signal format selector. The development and manufacturing cost of hundreds of SKUs is quite high; and it's also very difficult to manage the stock to keep the right amount of each SKU in stock in anticipating the user orders (which is virtually impossible). The resellers face the same inventory challenge too.

4	8	12	15	16	18	20	24	28	32	36	40	44	48	52	56	60	64
4x4	8x4	12x4	15x15	16x4	18x18	20x4	24x4	28x4	32x4	36x4	40x4	44x4	48x4	52x4	56x4	60x4	64x32
4x8	8x8	12x8		16x8		20x8	24x8	28x8	32x8	36x8	40x8	44x8	48x8	52x8	56x8		64x48
4x16	8x16	12x12		16x12		20x12	24x12	28x12	32x12	36x12	40x12	44x12	48x12	52x12			64x64
4x20	8x20	12x16		16x16		20x16	24x16	28x16	32x16	36x16	40x16	44x16	48x16				
4x24	8x24	12x20		16x20		20x20	24x20	28x20	32x20				48x32				
4x28	8x28	12x24		16x24		20x24	24x24	28x24	32x24				48x48				
4x32	8x32	12x28		16x28		20x28	24x28	28x28	32x28				48x64				
4x36	8x36	12x32		16x32		20x32	24x32	28x32	32x32								
4x40	8x40	12x36		16x36					32x48								
4x44	8x44	12x40		16x40					32x64								
4x48	8x48	12x44		16x44													
4x52	8x52	12x48		16x48													
4x56	8x56	12x52															
4x60																	

6) **Reliability challenge**: Because the central box does everything, it's a single point of failure. When this box fails, the whole system fails. Imagine a 256x256 matrix in a stock exchange like NASDAQ distributing the stock info to all the displays, what would happen if that matrix fails? The Murphy's law tells us "Anything that can go wrong, will go wrong". Bigger the matrix, more complex it is, and more heat it generates, and easier it fails; even worse, more difficult it is to repair.

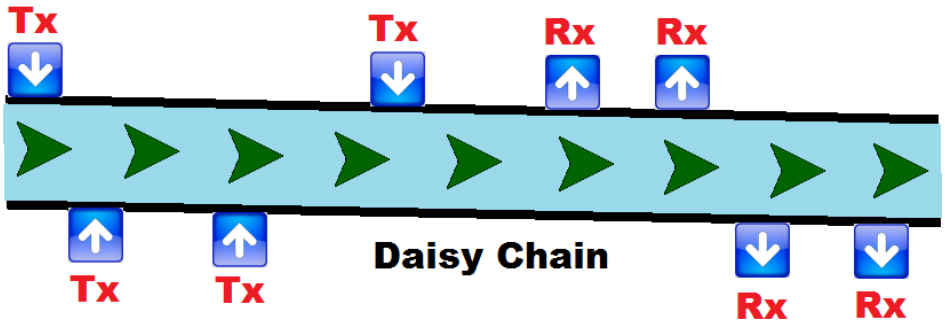
The distributed AV switching, a game changer

Just the fact that the central switching has been used for almost a century does not mean it's the "right" way or at least the only way or the best way to form AV systems.

A California, US based startup company Luxi® Electronics Corp was determined to challenge the century old central AV switching topology and invented an "Out of Box" approach called "Distributed AV Switching". The system topology is called "Daisy Chain". "Presenter®" is a registered trademark of Luxi Electronics Corp for its patent pending product line using the distributed AV switching.

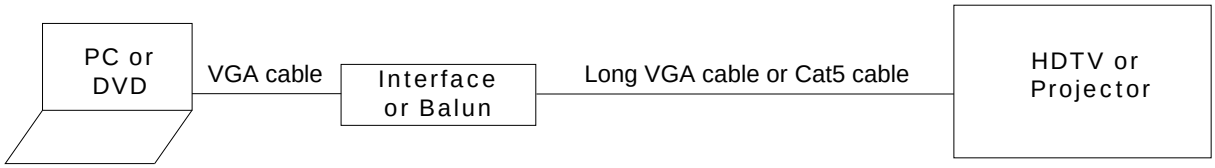
The basic concept of the Luxi distributed AV switching is to connect each source device to a Presenter transmitter (short for Tx); connect each display device to a Presenter receiver (short for Rx). Each Tx and Rx has two RJ45 connectors; one for daisy chain input and one for daisy chain output. The system is formed by daisy-chaining each Tx and Rx in series with a single Cat6 cable. The system switching is achieved by controlling which Tx inserts its local signal to the chain. The system distribution is achieved by controlling which Rx extracts which signal from the chain to the local

display. By using multiple pieces of the same Tx and the same Rx, we can form systems of any size without any central box! Imagine this daisy chain system as a river flowing thru all the Tx and Rx devices; each Tx is a port to load signal to a boat; each Rx is a port to unload the signal from a boat.

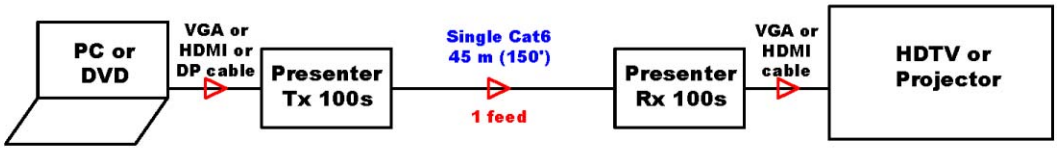


Multiple signals are allowed to flow thru the daisy chain (river) to achieve true matrix switching. See the system diagrams below:

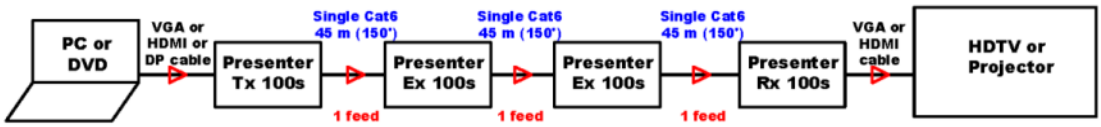
- Traditional interface or baluns system diagram



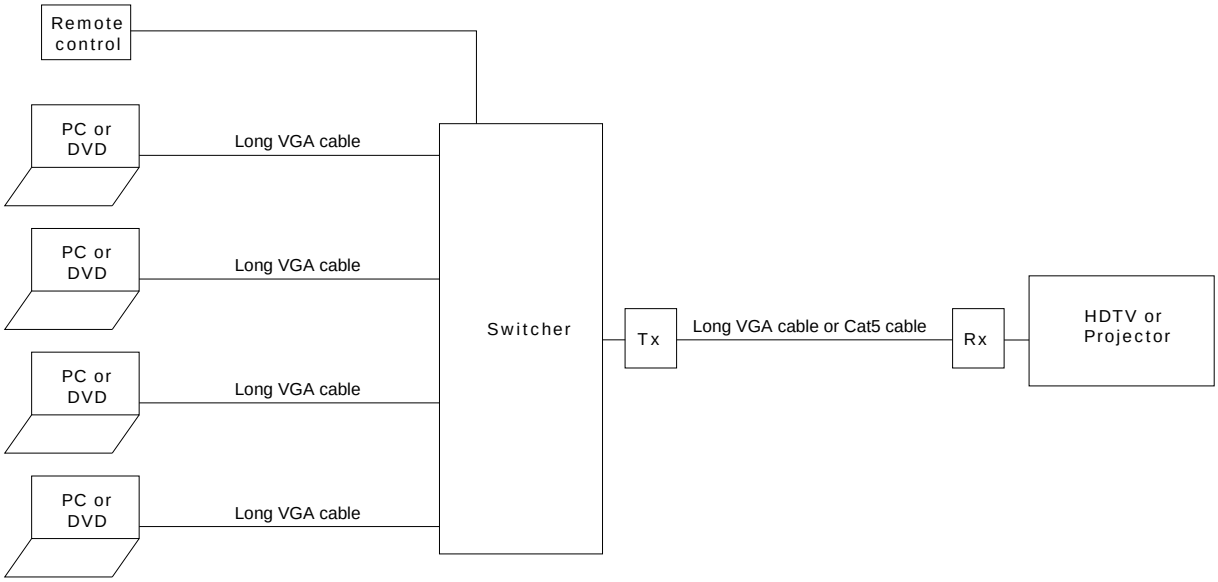
- **Presenter Tx and Rx system as interfaces, baluns or scalers**



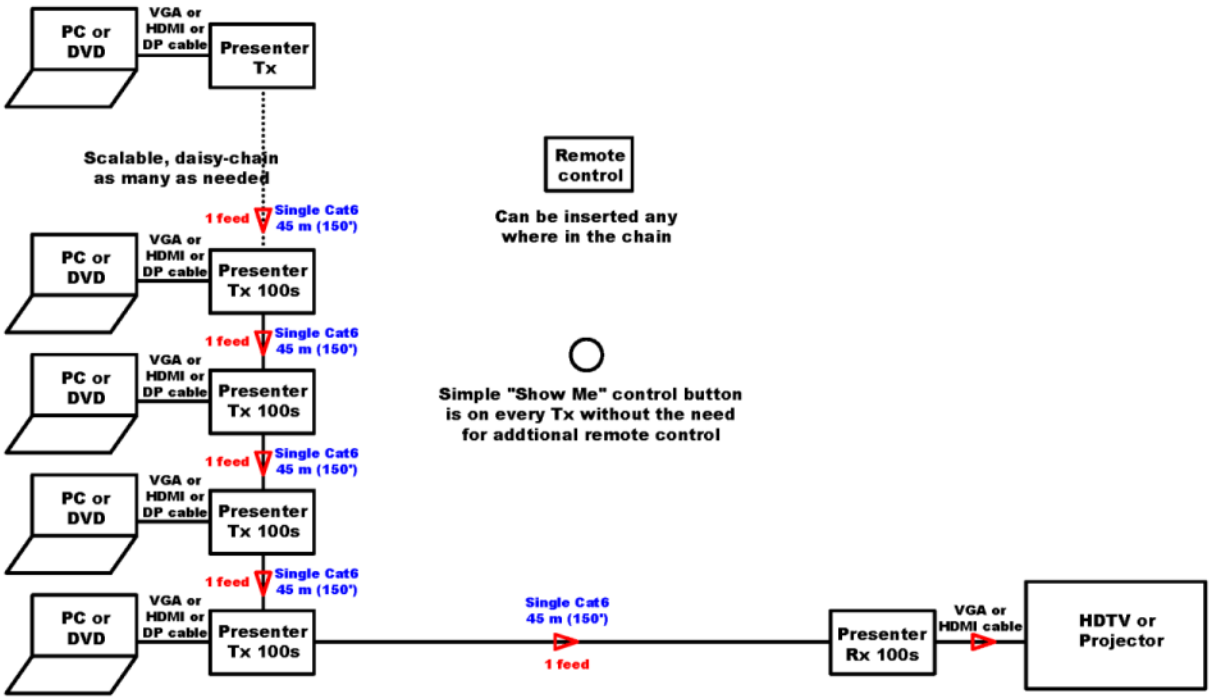
- **Presenter daisy-chained Tx's and Rx's for unlimited long distance transmissions**



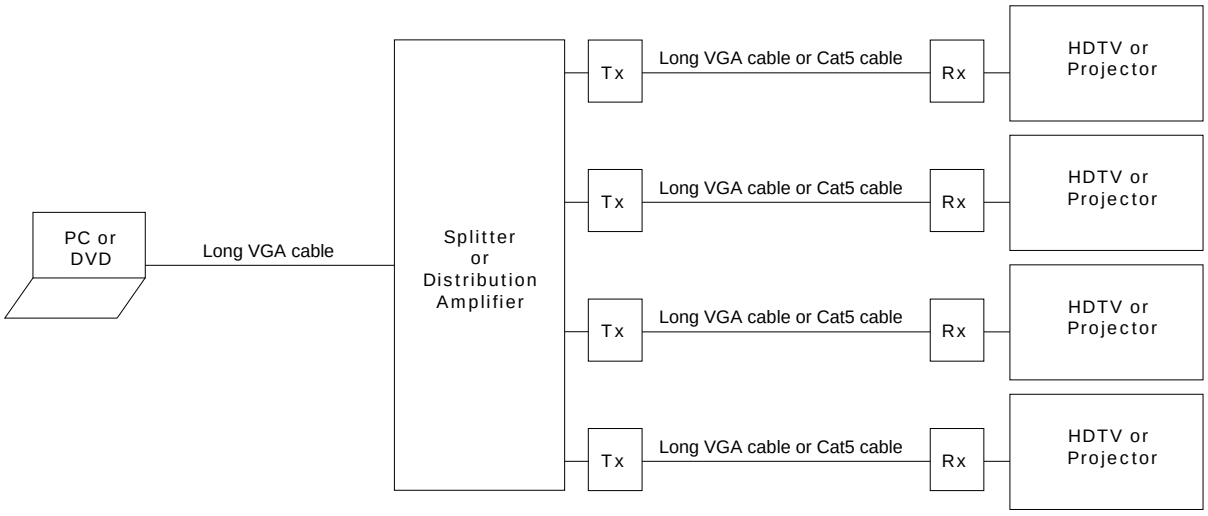
- Traditional switcher system diagram



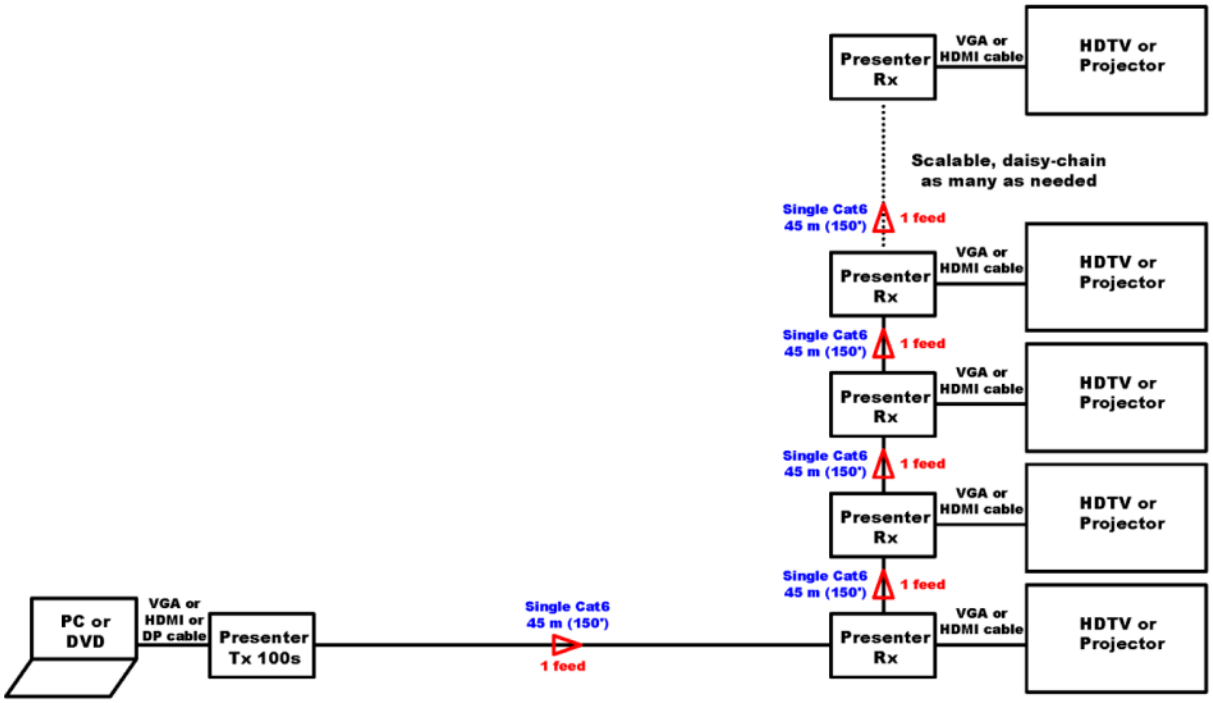
- **Presenter daisy-chained Tx's and Rx as switchers**



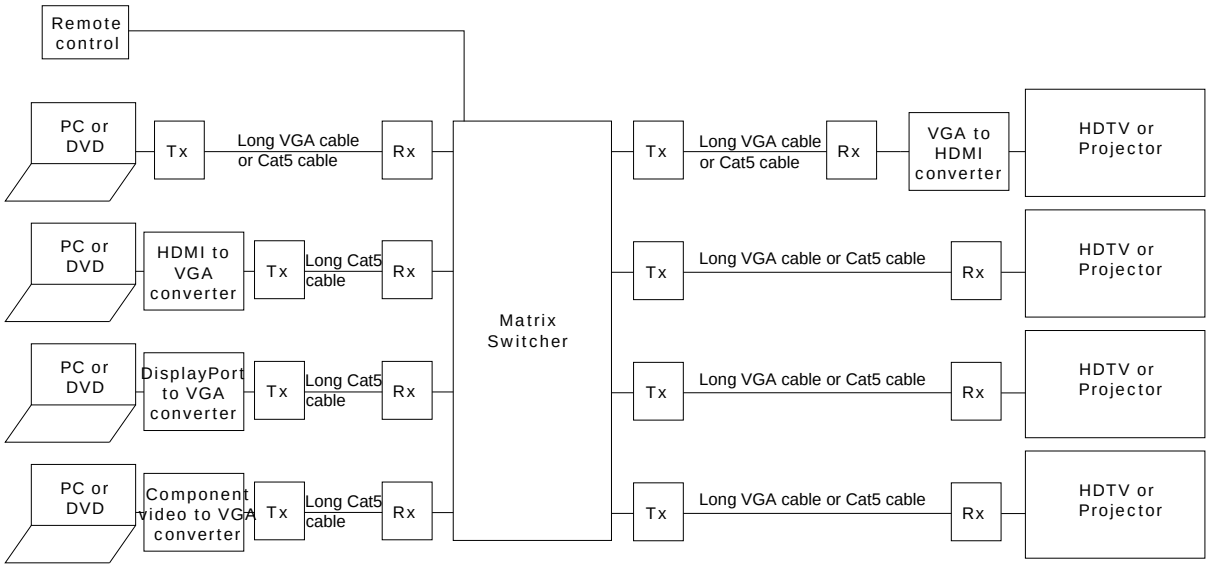
- Traditional splitter or distribution amplifier system diagram



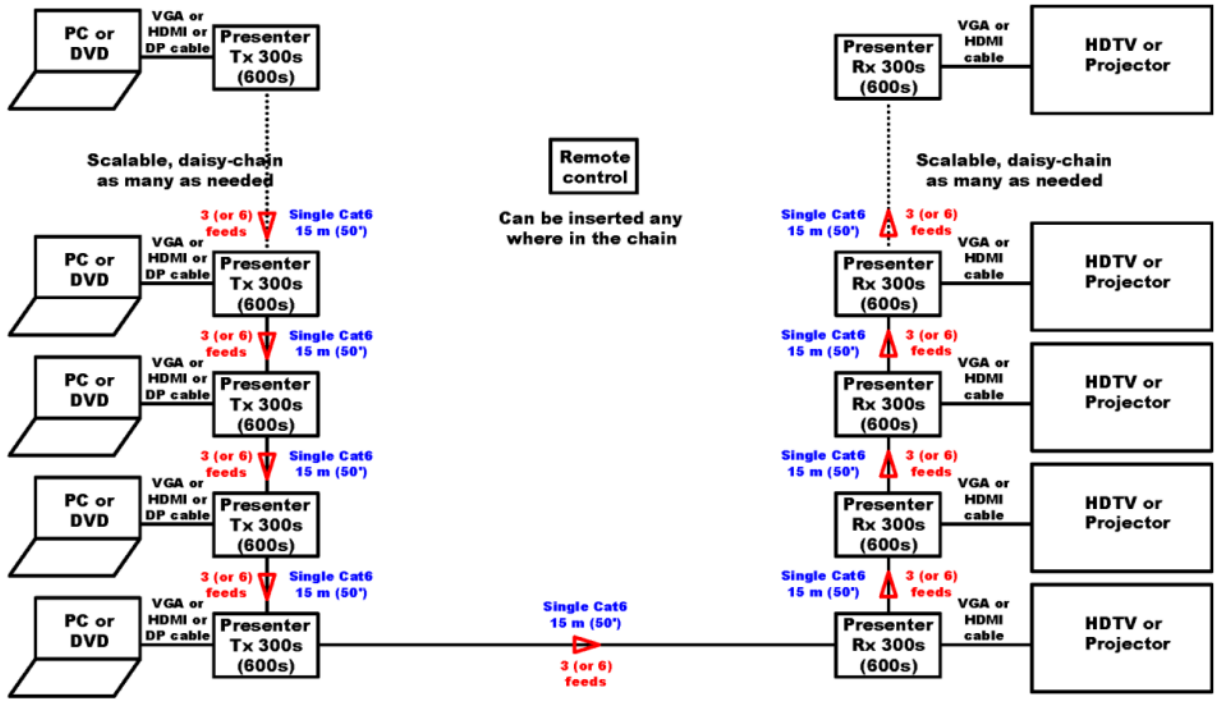
- **Presenter daisy-chained Tx and Rx's as splitters**



- Traditional matrix switcher system diagram



- **Presenter daisy-chained Tx's and Rx's as small matrix switchers**



Each Tx has a built in scaler to convert VGA/audio, component video/audio, HDMI and DisplayPort signal at any resolution or refresh rate to a common digital format chosen by Luxi for flowing thru the daisy chain. Each Rx also has a built in scaler to convert the common digital format to a VGA/audio or HDMI format at the matching resolution and refresh rate to the local display. To reduce cost, we also have a simplified Tx and a simplified Rx without the built in scaler. The picture of these products is here:

The 2 smaller boxes on top are the simplified Tx and Rx without scaler; the 2 bigger ones on the bottom are the Tx and Rx with built in scalers. The highly visible yellow RJ45 connectors are for daisy chain input and output.

By daisy chaining Presenter Tx and Rx boxes, we can form baluns, switchers, splitters, matrix switchers and scalers of any I/O size! This revolutionary distributed AV switching resolved all challenges the traditional central AV switching systems face:

1) **Cable installation advantage:** There's only one Cat6 cable in any spot of a daisy chain; and since no more need to run all cables to a central box, the installer can simply daisy-chain one box to the next closes box, the cable installation is much easier. Using the previous 20-PC conference room example, now you can just daisy-chain 20 Tx boxes mounted below the table with short Cat6 patch cords in between, and run a single long Cat6 from the table to the Rx next to the display.

2) **Cable length advantage:** Because there's no need for home run all cables to a central box, each cable becomes shorter. In addition, each Presenter Tx or Rx also functions as a repeater (refreshing the digital signal), the signal can go from one Presenter box to the next to achieve virtually unlimited total distance. For example in an airport information system, with the traditional central topology, each arrival

and departure monitor needs to be connected to a central matrix with cables as long as several km (miles) long. With the distributed system, the signal can be relayed by the Presenter Tx or Rx from one display cluster to the next which is usually not too far away from each other.

3) **Mix signal format advantage:** Each (full function) Presenter Tx and Rx has built in scaler. All source signals of different format and resolution are scaled to a common digital system format by each Tx, flowing thru the daisy chain, and then each Rx scales the common signal format to the local format and resolution to match each display. This approach greatly simplify the signal format handling and also makes signal switching super-fast because each signal is readily available at each Rx box; all the Rx needs to do is to pick which one to be decoded to the local monitor; there's no need to have source-display redo the handshaking. The HDCP is also handled locally at each Tx box, and again locally at each Rx box, the whole system is fully HDCP compliance.

4) **The system upgrade or expansion advantage:** The Presenter daisy chain system is completely scalable. You can expand or shrink the system I/O size by simply adding or removing more Tx or Rx boxes. Since all signals are converted by each Tx to a common format, you can easily replace the Tx for anther Tx with different or new input format when needed while it will be compatible with all other Tx and Rx in the existing system.

5) **SKU and inventory management advantage:** The Presenter solved this biggest headache of the traditional central AV switching with a super clean solution: only 2 SKUs (1 Tx and 1 Rx)! Imagine the resellers only need to keep inventory on 2 SKUs; installers only need to be trained on 2 SKUs and the customers only need to keep 2 SKUs as spare parts!

6) **Reliability advantage:** Each Presenter box is much simpler and generates much less heat than a central switch box, so the chance for each Presenter box to break down is much lower than a central box. When a box or cable in a Presenter system breaks, the software will alert the operator right away about it and the exact location of the failure (e.g., between Tx 8 and 9). Unlike the central system, a distributed system would still partially function when something breaks. For example, if the cable between Tx 8 and 9 is cut, the signals from the upstream of Tx 9 won't be able to flow down the daisy chain, but the signals from Tx 8 and all downstream Tx and Rx boxes will still work. More importantly, it talks a couple of minutes to replace a small box with only 3 cables attached to it to fix the problem; and the replacement boxes are most likely in customer's stock because there're only 2 SKUs to stock.

The system control advantage: Every Presenter Tx or Rx box has a RS-232 port and all the RS-232 ports in the system are connected in two way communications. This means that the user can plug in his control device to any RS-232 port of any Presenter box and control every Presenter boxes AND every source or display

device connected to a Presenter RS-232 port anywhere in the system. This is a very versatile and powerful feature.

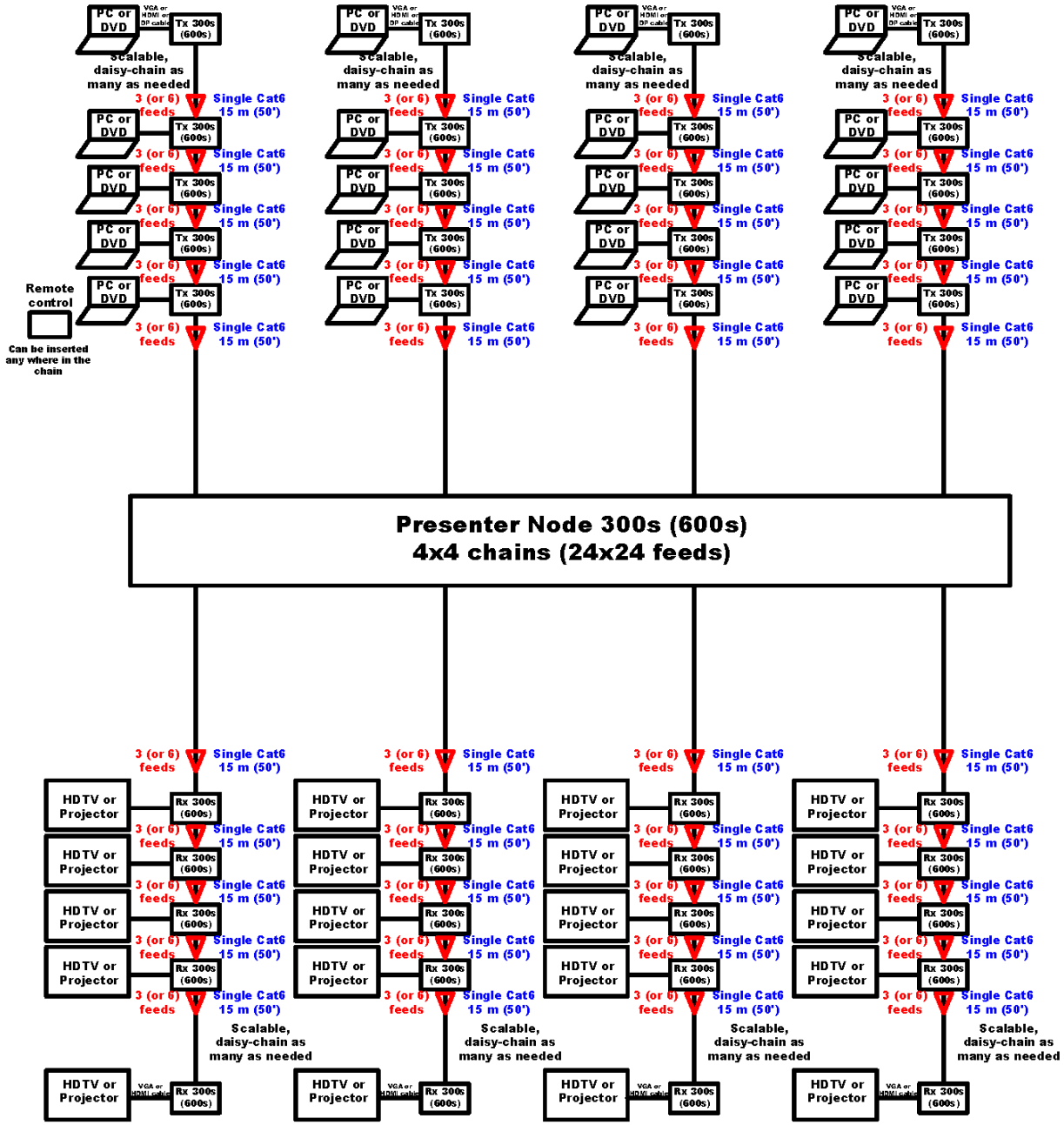
The current limitations of the distributed AV switching system:

Nothing is perfect. Here are some limitations of the current distributed solution:

1) **The bandwidth limitation:** Unlike the central system in which one cable carries one signal; each cable in a distributed system carries all the signals. Due to the bandwidth limitation of the copper Cat6 cable, we can only send up to 6 different signals (we call it 6-feed) over one Cat6 cable. This is NOT an issue for any systems function as baluns, switchers, splitters or scalers because by definition there's only one signal selected at a time. For example, in a 100 x 1 switcher system, although there are 100 source devices, but only one would be selected at a time. So for balun, switcher, splitter or scaler systems, even a one-feed Presenter system would work. This limitation would only affect the matrix system. With a 6-feed matrix system, you can still have unlimited number of source devices and unlimited number of displays, but only 6 different source signals can by chosen at any given time and only 6 different contents can be shown on all displays.

   Luxi Electronics Corp is working on two solutions for the bandwidth limitation. One is to utilize fiber as the cable for the daisy chain. The vast bandwidth of fiber would allow a lot more feeds to be sent at a time. Now the bottleneck is the bandwidth limitation of the semiconductors (ICs).

   The other solution is to add a device called Node (short for Nd). Each Nd has 4 input connectors, each can connect to a full daisy chain of many sources (but up to 6 selected feeds). Each Nd has 4 output connectors; each can connect to a full daisy chain of many displays (but up to 6 contents at a time). With 3 SKUs, a Tx, an Rx and an Nd, now we can expand the system to unlimited sizes (multiple Nds can be added to connect many more chains). See the diagram below. You can tell that we utilized both chain and star topologies for a very flexible system. For example, you have multiple devices in several rooms. You can use a single daisy chain for all the devices in each room, and then connect the chain of each room to a Presenter Nd. This way you can send signals from any room to any room, while still maintain the single cable chain in each room for easy installation.



Presenter Tx's, Rx's and Nd's as Large Matrix Switchers

2) **The relative higher cost for very small systems:** For very small systems like a 2x1 switcher or 1x3 splitter, the traditional central box solution would cost less than the distributed system because there are more boxes involved in a distributed system. For all systems bigger than that, or systems involved in long cable (where

the Tx and Rx boxes also required for the central system), or systems with mixed signal formats (where the scalers also required for the central system), the distributed systems have the advantage in cost most of the time.

3) **The less relevance for systems with all sources and displays in the same rack**: In these systems, the central box is still the cleaner approach.

Why the distributed AV switching is invented now, not earlier

As described above, the signals in a distributed system flow from one Tx or Rx box and to another box and another box and so on. This daisy chain topology is only made possible with the digital signals. In an analog daisy chain system, the signal quality degradation thru each box accumulates; so after 3 or 4 boxes, the signal quality is no longer usable. In a Presenter digital daisy chain, each Presenter box re-encodes the signal and eliminates any jitter or error from the previous box, so the signal is as good as new after each box and the daisy chain can go on unlimitedly without accumulated signal quality degradation. It's only possible after the AV industry shifted to digital with the HDMI and other technologies.

IT based AV signal streaming systems

Both central and distributed AV switching systems are AV based systems.

In recent years, the IT based solutions are used more and more in the AV industry. Many companies' AV department is now a unit of their IT department.

You cannot assume a product with RJ45 connector as an IT based product. The Presenter products discussed in detail above are NOT IT based products even they use Cat6 cable and form a chain which reassembles the token ring in the IT world.

The key differences between an AV and an IT based system are:

1) An AV system uses dedicated physical connections between source and display devices while an IT system uses virtual connections between source and display.
2) An AV system sends sequential data without delay; while an IT system sends packetized data with delay.
3) An AV system does not use compression; while an IT system uses compression.

The advantages of the IT based solutions are very obvious:

1) Standardized, widely available and often cheap network hardware.
2) Flexible signal format; you can send audio, video, files, PowerPoint, basically anything digital over the network.

3) Very far reach. Communication companies have invested billions of dollars for the networks like Internet, cell phone network, satellite, Wi-Fi, and they cover just about every corner of the world.

There are several challenges for sending AV signals over IT network:

1) **Bandwidth challenge:** An uncompressed 1080p 60 Hz signal has a data rate of about 4 Gbps. There's still no public available network can handle such a massive data rate. The typical data rate of an Internet connection is only 6 to 50 Mbps; most widely used 100BaseT Ethernet is only 100 Mbps. The Gigabit Ethernet is still in its infancy. So any AV signal must be compressed first before sending thru an IT network. The AV compression lossy, meaning the reproduced signal is not as good as the original.

2) **Latency challenge:** The packetized IP network has inevitable and often unpredictable delays. In addition, the encoder and decoder introduce their own delays to the signals too. When there's compression, there's delay. Video compression has very high compression ratio and must utilize the intra-frame compression. For the intra-frame compression to work, the encoder or decoder must store the digital signal into a buffer (memory) of several frames and perform the complex calculation among these frames. This would cause 2 to 14 frames or 60 to 500 ms of delay. If the content is a continuous media like a movie, it's not too bad. But for critical tasks like surgical equipment control or even the simple video game playing, this latency is not acceptable.

3) **Quality of service challenge**: Utilizing the general purpose network is the biggest advantage of the IT based solutions; it's also its biggest potential problem. A shared network like the Internet will have data traffic jams. You see so often the rotating arrow when you watch YouTube even with very fast Internet connection for the very low data rate video.

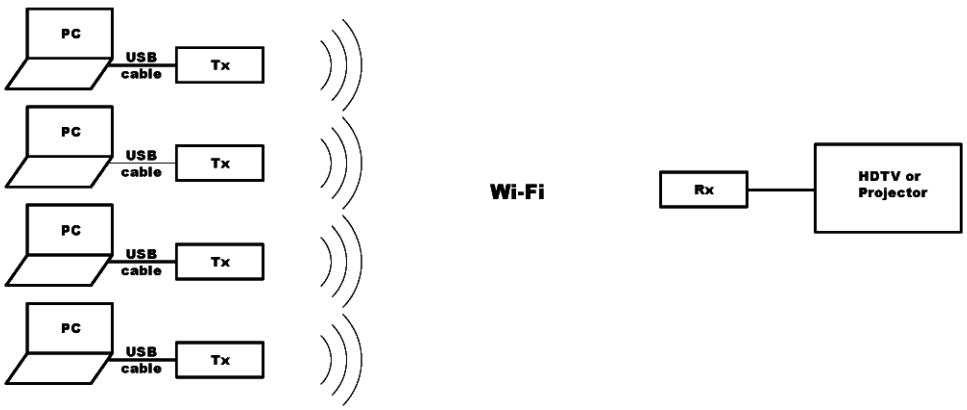
4) **Security challenge**: This is another byproduct of the general purpose network. The security defense of an AV system is that the dedicated cables are physically installed in the secured building so the thieves have no physical access to the signal. The security defense of an IT system is that everyone on the network, including the thieves, can get the physical signal; but the authorized users can decrypt the physical signal while the thieves (hopefully) won't be able to decrypt the signal even they can physically receive it. You know how secure it is ☺.

5) **The cost challenge**: This might be a big surprise for some. The low cost of hardware supposes to be the strength of IT based system. But that refers to the network hardware. The real time high quality video encoder (compression device) is very expensive. They were so expensive in the past that only TV stations, DVD master companies and government could afford them. The prices have come done a long way now they start getting into the pro AV industry. But last time we checked

the prices were still in the tens of thousands dollar range. Another cost is the monthly network fees based on the amount of data sent. Higher the data sent, more expensive.

There are two main types of IT based systems intended for the pro AV industry; one is desktop sharing and the other is media streaming.

Here's an illustration of a **desktop sharing** system:



Desktop sharing

A small box connects to each PC via a USB pigtail. The software takes a snapshot of the PC desktop screen, and sends it to the receiver via Wi-Fi. Each box also has a click button on top. If one button is clicked, the desktop of the connected PC would be sent to the receiver and displayed on the projector. If more than one button is clicked, the desktop screenshots of the associated PCs would be shown on the projector as small windows.

Here's a brief comparison between the desktop sharing to the distributed AV switching system like the Presenter products:

Pro:

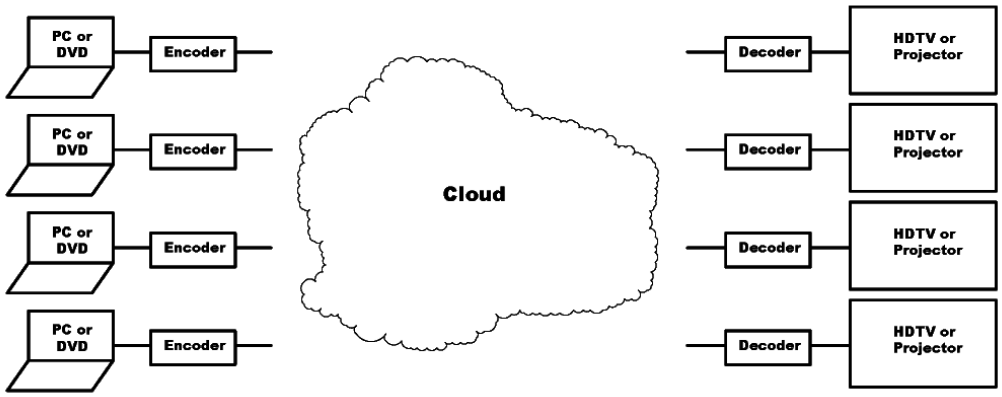
1) Wireless, easy to install
2) Multi-window to compare info from several computers
3) Multi-platform support, PC, Mac, etc.

Con:

1) Low refresh rate; I estimated it at only about 4 fps with the prototype; the mouse cursor jumps on screen and the video clips are choppy
2) Cannot play any HDCP protected video; black screen
3) Limited to 4 computers
4) Wireless security concerns

5) Wireless reliability concerns
6) $6000 for a 4 mouse combo; much more expensive than the Presenter
7) Limited to conference room applications

The other IT based system for AV industry is the **media streaming**; see the system illustration below:



Media Streaming

This is a very typical streaming system. Some products improve the compression quality, latency, security. But all the pros and cons discussed in the general IT based solutions for AV apply here.

Conclusion:

In this whitepaper, we discussed 4 main AV signal distribution methods in the pro AV industry; the AV based central and distributed switching, and the IT based desktop sharing and media streaming. All 4 methods have pros and cons; see the comparison table in the last page. For very small AV systems, or the systems where all the sources and displays are in the same rack, the central switching system works the best. For small conference room collaborations, the desktop sharing can be a handy solution. For interstate content sharing, the media streaming is the only solution. For everything else, the distributed switching solution is a game changer.

Electronics technology edge keeps advancing following the Moore's Law. The landscape of AV distribution may change dramatically 5 years from now. But one thing never changes over time: the companies that innovate and adapt will lead.

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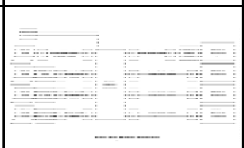
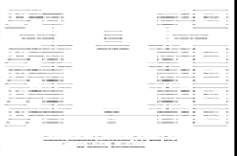
Pro AV signal distribution method comparison

	AV based		IT based	
	Central switching	**Distributed switching**	**Desktop sharing**	**Media streaming**
How it works	All source signals are sent to a central switching device, then are distributed to all displays from that central device after switching	Each source is connected to a Tx device; each display is connected to a Rx device; all Tx and Rx devices are daisy-chained to form a large system; signals flow in the daisy chain	The contents of computer desktops are grabbed by a computer software and sent to a receiver via network; the receiver reconstructs the desktop content and sends it to display	AV signals are compressed and packetized by the encoders, and are sent thru network; decoders receive the packets and reconstruct the media for the displays
System diagram				
Dedicated connection	Yes	Yes	No	No
Latency	None	None	Several video frames	Several video frames
Quality of service	Guaranteed	Guaranteed	Good to poor	Good to poor
Video frame rate	As high as the source signal	As high as the source signal	Up to 20 fps	Varies depends on the encoder and network quality
Max video resolution	As high as the source signal	As high as the source signal	Up to 2048x1536	Up to 1080p
Compression (video quality loss)	None	None	Yes	Yes
Send computer image	Yes	Yes	Yes	Yes
Send copy protected video	Yes	Yes	No	Yes
HDCP compliant	Yes	Yes	No	No
Cables for each link	Multiple cables	One Cat6	None (wireless)	One Cat5 or Cat6
Cable installation	Difficult	Easy	N/A	Easy
Max distance	Up to 100 m (300')	Unlimited	Up to 30 m (100')	Unlimited
Max I/O numbers	128 x 128	Unlimited	4 x 1	Unlimited
Max number of signals per link	1	Up to 6	1	Many (with compression)
I/O expandable after installation	No	Yes	No	Yes
Multiple video format support	Requires scaler at each I/O with different format than the system format	Yes	N/A	Yes
Central switcher/router cost	Very expensive	None	N/A	Moderate (general network router)
Tx, Rx, encoder, decoder cost	Moderate	Moderate	Moderate	High quality encoder very expensive; decoder moderate
Small system cost (i.e., 4x1, 2x2, 1x4)	Cheap	Moderate	Moderate	High quality encoder very expensive; decoder moderate
Monthly usage cost	None	None	Cheap (low cost Wi-Fi service)	Can be expensive for high data network charge
Security (difficulty for illegal access to the signal)	Very good	Very good	Poor	Poor
Security (difficulty for illegal signal decryption)	Poor	Very good	Poor	Good to very good
Future proof	No	Yes	Yes	Yes