

Art-Net Seminar By Wayne Howell at PLASA09

A 'Light' History

More than 30 years ago, the first remote lighting control desk used analogue multicores to control dimmers. This was achieved using a single wire that controlled a single channel. This method meant different companies used different voltages, cables and/or connectors and it required exceedingly large cables travelling from the desks to the dimmers.

The first move to solve this problem was to use analogue multiplex - Using Time Division Multiplexing to transmit multiple channels using a single cable. In essence this meant chopping up the signal and relaying it down to the multiplexing box. This resulted in multiple formats.

- AMX192
- D54
- S20

Analogue protocols allowed us to transmit multiple channels but they suffered from an excess of problems such as short distances and noise pick up.

The next improvement was to take the TDM concept and go digital with it. By doing this we could go to greater distances and obtain much more reliable results. It was less susceptible to noise pick up and had a higher channel count.

Again, there were numerous companies with proprietary protocols. The solution was brought to us as DMX512 that meant the industry now had a standard that all manufacturers could comply to. It was developed by USITT and managed by ESTA.

The main specifications of DMX512 are;

- 512 channels per cable
- 300m maximum distance
- 32 fixtures per cable
- Refresh rates upto 40 frames per second
- Digital signals so less susceptible to noise
- Free for the industry to use

Networking

DMX512 worked very well within the industry until pixel based LED control came along causing the channel count to go through the roof. By the time networking began to appear, consoles were already being built with 8 DMX connectors on the rear. The industry had returned to the same problem with analogue multicore and now what we needed was a way to have DMX multicore. This was where the entire concept of using networking for lighting control came in.

As the industry saw before several manufacturers developed their own solutions to this problem such as;

ShowNet - Strand was first with their protocol

ETCNet - Created by ETC
other proprietary protocols
cast WYSIWYG

We felt the need to use standard network technology for the development of products such as digital multiplex for many DMX lines over an Ethernet cable. However there was no success gaining access to protocol data from other companies.

This forced us to develop our own protocol to transfer DMX over Ethernet, which is now what we know as Art-Net. We were not the only company who felt that there was a need to move a number of DMX universes over networks, so we made the move to publish the protocol for everyone to make use of. It was greatly appreciated within the industry. With ADB being the first to adopt, we now have over 100 manufacturers utilising Art-Net.

It has no formality in terms of being a recognized standard by any of the trade organizations or standardization bodies, nor are there any licensing terms. We published it so that anyone in the lighting industry can implement Art-Net within their products with no licencing costs, use it if you would like to.

Ethernet – Why Use it for Lighting?

There are many pros worth noting when it comes to using Ethernet for lighting.

- By using networking, we get to use the existing network protocol and associated equipment. Not only do Protocols such as Art-Net and EtcNet sit at a high level on networking over proven protocols like TCP and UDP, they do so without us worrying about the nuts & bolts of how information gets from A to B.

- Another pro is the low cost Cat-5 cable - generally speaking contractors don't understand (or like) the XLR5 cable - where Cat-5 cable has become common place within buildings.

- Networking gives us higher bandwidth (10BaseT allows for 40 times more data than DMX cable does).

- From an installation point of view, modern buildings already have an Ethernet infrastructure in place.

- Using Ethernet, there is the ability to make use of ongoing development within the IT industry, hence minimal product redesign.

- Cost-wise, IT equipment and cables have (and continue to) become ever cheaper.

- We also benefit from the existing IT market technology which is pushed by a high research & development budget, while our (lighting) industry generally hasn't got that kind of support.

- Ethernet can be transmitted over a wide variety of media including wifi, laser, telephone, ADSL, ISDN, and Fibre Optic

- All modern Ethernet wiring is in star format, point to point. Hence allowing us to configure and re-configure easily and providing greater reliability. If you disconnect a connector and you know

you are disconnecting only one device from the network. On the other hand with DMX you are disconnecting from 1 to 32 devices!!

Unfortunately, Ethernet comes with its downsides. It can run only up to 100m, and looping DMX is easier as opposed to using cable for each device in a star network for Ethernet, or have further electronics on the truss. Ethernet is also less forgiving and much higher level of knowledge is frequently required from the people dealing with it and fault finding.

The Benefits of Art-Net

Art-Net allows us to remotely patch all the DMX universes it carries. Conceptually Art-Net remains multi-core, carrying multiple DMX lines. A DMX universe is added to the network and tagged with the address. The address is notionally one of 256 universes.

The beauty of Art-Net is the ability to remotely reconfigure the address and therefore completely re-direct data traffic.

Art-Net also supports RDM allowing precise configuration over RDM enabled DMX fixtures. This allows remote start address programming and more importantly information from the fixtures can be received from the controller, such as temperature sensors. This allows DMX equipment and techniques to be used with the Architectural Industry.

In addition Art-Net also allows macro triggering, the industry has open access to the protocol, it is free to use and is in the public domain. It can be used with other resources including DMX-Workshop (available from Artistic Licence), wire shark, and Net-View allows monitoring via radio networks. An SDK for the software drivers are also available.

So does this mean DMX is dead? No!

Art-Net is used to transport multiple universes from the controller and then DMX is used to do the last few hundred metres and connect to the actual fixtures. DMX is very robust and can connect to multiple fixtures unlike Art-Net.

A Networking Primer

Ethernet is less forgiving than DMX. There is also a great deal of confusion about the terminology regarding Ethernet. Ethernet is a specific type of networking (10mbps) and fast Ethernet is 100mbps.

There is further confusion regarding media types. From a copper point of view we use Cat numbers to define the cable types. They originally started for use in telephone systems (Cat-1 through to Cat-4). Networking began with Cat-5 cable, which was suitable for speeds upto 100mbs. Other types of cables we see are Cat-5e, Cat-6 (the cost is beginning to come down) and Cat-7. Most building installations use either Cat-6 or 7 cable now to ensure they are future proofed.

Ethernet Physical Layer

It is the way in which the signal modifies and speed in which it runs.

What does 10BaseT mean?

10 = a multiplier for mega bit per second.

Base = it is base band (only one signal on physical wire), on the other side, in broadband you have multiple signals modulated on one wire.

T = twisted pair.

10Base2 is mentioned largely for historical interest and stems from when the network industry began. It was non-robust way of transferring data.

10BaseT has maximum cable distance of 100m. Most of the DMX Ethernet style converters in the industry right now are either rolling over 10BaseT or it is their base level protocol.

100BaseT is 10 times faster than 10BaseT and can send data at 100mbs.

While you cannot make a direct comparison between DMX data rates and Ethernet bandwidth, you can make a hand waving comparison that says 10BaseT is comparable to 40 universes, hence 100BaseT is 400 universes.

100BaseFx is fibre optic. It is being widely used as the backbone of the Ethernet distribution system for the installation of lighting control.

1000BaseT is now commonly seen and is sometimes referred to as Gigabit. Its primary use is video streaming application and console to console communication.

There are 3 type of copper network.

- Coaxial - we can largely ignore this as it is a very old protocol.
- UTP - unshielded twist pair. 99% of installations we see use UTP.
- STP - used only in very noisy environment. We have seen only a handful of instances where there was good reason to use shielded cable.

There are 2 types of construction of Ethernet cable, solid conductor and stranded type. If you are using stranded type which is quite possible in this industry then you are actually reducing the cable length to 80m!

Some RJ45 connectors are designed specifically for rigid cable and some for stranded but they appear very similar. If you use the wrong connector you may find the cable coming off after just a couple of months. The remaining types of connector are from Neutrik and there are waterproof (IP rated) ones from Woodhouse.

Ethernet wiring schemes

In an RJ45 connector there are 8 cores. Signals travel on twisted pair hence we effectively provided with 4 circuits. Some protocols use only 4 wires and some use all 8 wires. The reason for mentioning this fact is that the more important use coming up in future is the ability of having the power through Ethernet.

There are 2 ways to have power down the cable. If you are using one of the simpler protocols with 4 wires you can use the remaining 4 for power. If you are using protocols which use 8

wires, more sophisticated modulation techniques have to be used so that the data signal sits effectively on top of the power. Thankfully, distribution products are looking after that for us.

Infrastructure based equipments

With Current networks that have upto 100m of cable we use electronics to redistribute data. There are two types of box we can use; one is called a Hub and the other is called a Switch.

A Hub is a particularly simple device not dissimilar to a basic DMX splitter, electrically cleaning up the signal and retransmitting it. All the data that is received is transmitted on all the ports. These have largely been replaced by Switches now.

The data coming into a Hub will appear on all of the connectors going out. That is in contrast to a Switch, which does something more intelligent. It analyses the data, buffers and retransmits it. A Switch will attempt to work out what is connected to the end of the cable, and send only the data which that has been sent to that device. It is useful for controlling bandwidth. It does however make fault finding somewhat harder, as you might not find the data you are looking for because it may not be coming out through that connector.

So Hubs are useful for fault finding purposes (you can only have 4 of them in line). On larger a network, a Switch should be used for bandwidth management (you can have as many as you like).

Under the Hood - Art-DMX

The key packet in Art-Net is called Art-DMX. This is used to transfer the DMX data over the Ethernet network. It can be generated within the actual controller or can be converted from a DMX source.

The Art-DMX packet contains three main pieces of information.

- 512 channels of DMX values
- 5 control fields including the universe number (to distinguish from others on the network)
- The order number. As some packets may be delayed it is important to include the order number so the receiver knows whether to ignore a packet that has arrived out of sequence

Broad/Uni/Multi Casting

There are three ways in which you can send data:

Broadcast, where you have one transmitter sending data to absolutely everything on the network.

Unicast, where there is a one-to-one relationship; data is transmitted to a specific IP address.

Multicast, where there is a one-to-many relationship. If you had 20 devices that all wanted to

consume the same data, you could use Broadcasting but that would mean those outside the group would be seeing that data as well. You could also use Unicast but you will be using 20 times as much data you really need it to. Alternatively, you can Multicast it. This means you are sending data only once but you are sending it to the addresses of the subscribed devices.

When we designed Art-Net, it was using broadcast. The user point of view was that it was low aggravation, low configuration. You plugged in, dialled the numbers and that was all there was to it. But this was when 8 universes was considered relatively large.

Since then things have moved further and the use of Broadcasting has become a problem as it simply burns the bandwidth. We evolved Art-Net on to Art-Net II in order to make use of more intelligent systems within the network. We had a choice of choosing Multicast or Unicast; Multicast would have been an intelligent decision but as Art-Net is a voluntary protocol the time would have been too costly. So Art-Net II uses Unicast.

The benefit of this method is that people can choose what level of sophistication they want to use. Where if Multicast was used the cost of implementation within controllers would have become costly due to the intelligence needed to manage grouping and subscribers.

Art-Net-II essentially starts with the broadcasting of data but it then uses a simple packet mechanism on the network to find out what universe the responders want to use.

Let's say for example there is a lighting console connected to the network and at the other end we have one box who wishes to output DMX universe 200. The console will send out the polling packet. The responders would say, 'I am consuming universe 200'. At that point an Art-Net-II console can switch from broadcasting to unicasting for that specific device. This is where we get a massive bandwidth saving, which really matters once you go above approx 40 universes of data.

If the console gets responses from 5-6 responders requesting DMX universe 200, rather than unicasting all of them it would drop back to broadcasting, as that is more efficient from a network bandwidth point of view. That is essentially the only difference between Art-Net I and Art-Net II.

ArtPoll is the mechanism used to find what universe the responders are consuming.

ArtPollReply is returned by nodes, such as Art-Net to DMX converters, dimmers and lamps, to report their status.

The console always begins with broadcast and hence is 100% backwards compatible.

The other critical aspects of Art-Net, from an installation point of view, is the ability to get the data back from the devices. Key to that is the new RDM protocol.

RDM (Remote Device Management) is a new protocol developed by ESTA. We had been sending data over pin 2 and 3 of the DMX cable for many years. What RDM does is every once in a while reverses the direction over the pins so that it can receive data from the devices. DMX becomes bi-directional and allows us to change the start address on the fixtures and even send data back to the device.

Large scale Applications

Broadgate

This is an installation undertaken several years ago in London involving roughly 600 colour changing fixtures installed in the ground. Artistic Licence was commissioned to design the technology implementation, from the fixtures through to control systems, identifying how programming and ongoing maintenance would work. This was a point when Art-Net I was used and RDM was very much still in development, although there was rough draft.

The installation was the first RDM (Draft) installation worldwide. It was also the first installation where we were transferring RDM using Art-Net. The system still used DMX however DMX was being transmitted as pure DMX going into the fixtures and DMX over Art-Net from Colour-Tramp to the main control racks. There was a consideration given to using Art-Net through the system but it would have complicated the wiring of the in-ground fixtures. We wanted to keep the power circuits and DMX circuits identical to each other so that we didn't encounter earth loop difficulties. From the containment point of view, there was a great deal of DMX cable coming into the control room but seven times less than there would have been if we had used Ethernet direct to fixture.

The sensors used were for measuring line voltage, temp, water, start address, lamp on time, fixture, firmware. All this information was sent from the fixtures to the Art-Net nodes using the RDM protocol and then Art-Net took it back to Colour-Tramp so the system could record the status of the fixtures.

Pan Peninsula - Ballymore properties

Located in the Docklands of London, both of the towers have large LED rails on them. We were asked to get involved with the lighting control, networking and also to do their opening show. For the opening show we had to be on top of the roof on the building approx 500M away so it could be coordinated with the main presentation. Because of the high channel count and distance this could not have been done using DMX.

We decided that there was a large amount of water between the building and where we were. Clearly this posed a problem, so we brought in some Ethernet radio products.

The show was to be run in sync with the orchestra. Here we encountered an interesting problem. The Ethernet radio was very reliable but the quantity of time needed to sync itself when powered up was between instant and 400ms. The delay of initial synchronization existed as an insertion delay for the data travelling between two buildings, and this did not look good at all. We experimented with products from three different manufacturers and at last found one which would start up reliably.

Noxx Nightclub

This was a recent project we were involved in, featuring a massive ceiling array of our pixel based LED products with approximately 60 universes of LED nodes. The controller that was used at the time of installation was using Art-Net I and therefore was attempting to transmit 60 universes of DMX over a 10BaseT Ethernet Line.

To overcome this issue we created a new software application overnight called Art-Route. It converts received Art-Net I packets and transmits them using Art-Net II, this resulted in the 60 universes of broadcast data being sent only to the nodes that needed it using the Unicast method.

UB40 Dub Sessions

This was an interesting application where no DMX was involved. Ethernet distribution was going directly to LED lights.

In the industry many people have the opinion that DMX is not fast enough for animations. A lot of this arose from the earlier implementation of network protocols used for the control of lighting which missed a very important point. When people use a console, by default the design of the console will have those universes synchronized with each other. The breaks of each of the universes would be within a couple of hundred micro seconds of each other. What began happening during early days is that they started converting from DMX to network traffic. Suddenly, the network traffic carrying all the different DMX universes wasn't synchronized any more - hence you would get horrible animation effect like a badly synced video with the edges ripped.

We always built the solution into our Art-Net products and now we have incorporated it in to the Art-Net-II specification; when converting back to DMX you must synchronize to incoming network data. If you don't, it would be fine for moving lights or conventionals where you can't see minimal differences between refresh light. But it would look terrible on a wall of pixels.

Q&A

1) The relationship with ACN of Art-Net

There is no relationship. ACN has now been released (a number of companies are using it including Strand, ETC, Horizon).

It is a very heavyweight protocol, requiring a significant level of processing power compared to a streaming protocol like Art-Net. It is one of the reasons why ESTA started the research program to generate a standard streaming protocol which is compatible with ACN. The generic name of this new 'standard protocol' is ACN Light. There are two variations;

1.31 - A program to generate a protocol to move standard DMX lighting packets over the network. Streams the data but in a way that is compatible with full blown ACN. Currently the draft version is in public review and is making good progress.

1.33 - A program that adds RDM to the protocol above. For upto date information on the progress of this program please contact ESTA.

2) What does it take for manufacturers to embed Art-Net directly into a lighting fixture (like having an Net-Lynx O/P within)?

Increasingly less and less. A significant amount of electronics and know-how was required to include Art-Net into a lighting fixture. However, we have recently developed a single board module that can be built into the product with only a few external components needed. This

module takes care of converting Art-Net to DMX. Along with the module an evaluation board is available.

3) Would it be beneficial to have a forum?

Yes. After feedback from customers and manufacturers we have created Art-Net.org.uk which is a resource for everyone that uses Art-Net. The site is being sponsored by Artistic Licence but will be for the industry as a whole.