NDI NETWORKING

Introduction

NDI® is an efficient, easy-to-deploy IP media transport standard supporting high-quality audio and video over low-cost networks. However, it is crucial to understand how NDI transport works and the requirements of the network for a successful deployment. In this paper, we will walk through the different flavors of NDI, the underlying network transports it utilizes, and what you need to know about building and configuring a network for NDI.

History of NDI

NDI was introduced in 2016 and has gone through many revisions throughout the years, with highlights outlined below:

Version	Year	Features
1	2016	Initial High-Bandwidth (SpeedHQ codec)
2	2016	Cross-subnet support
3	2017-18	NDI-HX (H.264), multicast support, PTZ camera support, embedded FPGA SDK
4	2019-20	Multi-TCP, NDI-HX2 (H.264/H.265), UHD, Discovery Server
5	2021-22	rUDP, NDI-HX3, NDI Bridge, NDI Router
6	2024	HDR Support and 16-bit color formats

NDI Versions are backward compatible, so, for example, an NDI 5 device should interact with an NDI 3 device based on the NDI 3 capabilities.

NDI Profiles

NDI implements several different transport & codec profiles. These are tailored to various applications.

NDI High-Bandwidth (NDI-HB)

This is the original NDI codec (sometimes referred to as NDI High Bandwidth or NDI-HB) and the most commonly used. It utilizes the SpeedHQ codec (a long-GOP MPEG-2 variant) that emphasizes image quality and low latency at a relatively high bitrate. It supports full-resolution and low-bandwidth preview streams. This is the preferred codec for high-bandwidth, low-latency professional AV and broadcast applications.

NDI HX

NDI HX (High Efficiency) utilizes H.264 long-GOP video and AAC audio codecs to achieve lower bitrates. However, it is subjectively lower quality and higher latency than NDI High-Bandwidth. HX2 has replaced NDI HX.

NDI HX2

NDI HX2 is an extension of NDI HX that adds support for the HEVC video codec and the Opus audio codec. NDI HX2 also supports UHD resolutions. NDI HX2 is the preferred choice when minimizing bitrate is the primary concern.

NDI HX3

NDI HX3 utilizes the same codecs as HX2 (H.264, HEVC, AAC, OPUS) but with a short-GOP structure (1 or 2-frame GOP) at a higher bitrate to optimize image quality and latency. It does this at about half the bitrate of NDI High-Bandwidth.

Profile	Bitrate	Latency	Codec	Quality
NDI-HB	100-160Mb/s	16ms	SpeedHQ (HD)	Great
NDI-HX/HX2	9-16Mb/s 20-30Mb/s 6-10Mb/s 15-20Mb/s	80-200ms	H.264 (HD) H.264(UHD) HEVC (HD) HEVC (UHD)	Good
HDI-HX3	25-60Mb/s 90-110Mb/s 20-50Mb/s 70-85Mb/s	<100ms	H.264 (HD) H.264 (UHD) HEVC (HD) HEVC (UHD)	Great

Transport Types

NDI utilizes several transport types, which fall into one of 2 IP protocol types: unicast or multicast.

Unicast

Unicast transports (TCP, multipath-TCP, UDP, and rUDP) are point-to-point. Each stream has one sender and one receiver. As shown in Figure 1, if multiple receivers wish to capture a stream, the NDI Source must transmit it multiple times. In this example, if the NDI stream is a 100Mb/s NDI-HB stream, the source would utilize 300Mb/s to serve the three receivers. Scaling issues can arise if a large number of receivers are interested in the same stream.

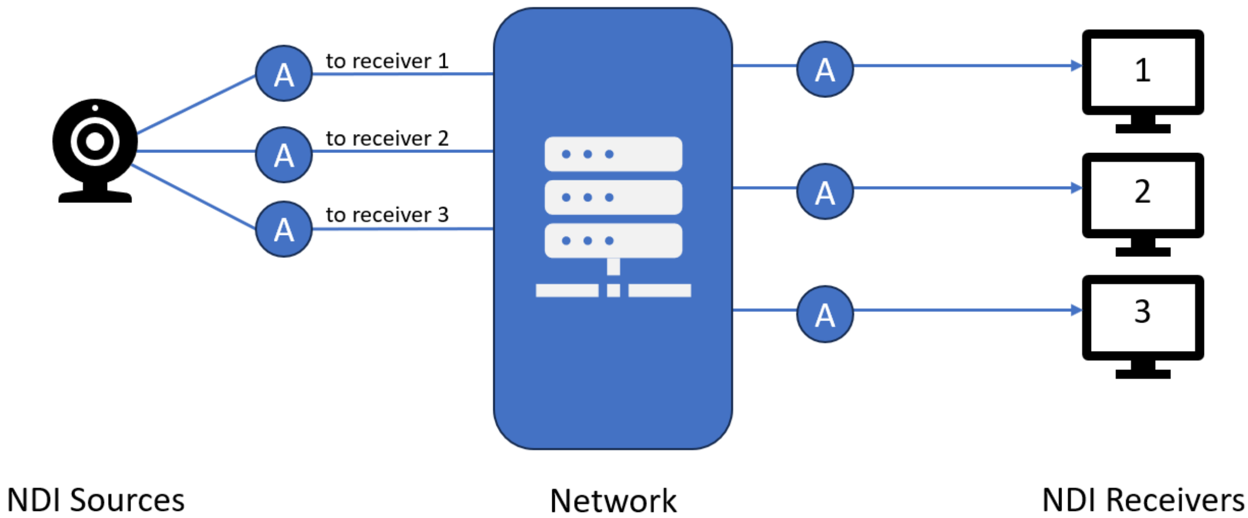

Figure 1 - Unicast Transport

Multicast

Multicast transport allows a stream to have one sender and multiple receivers, requiring a source to only send a stream once, regardless of the number of receivers. That reduces the processing of the source and its network utilization. As shown in Figure 2, the source only sends the NDI stream once, regardless of the number of receivers, and only receivers that subscribe to the stream will receive it.

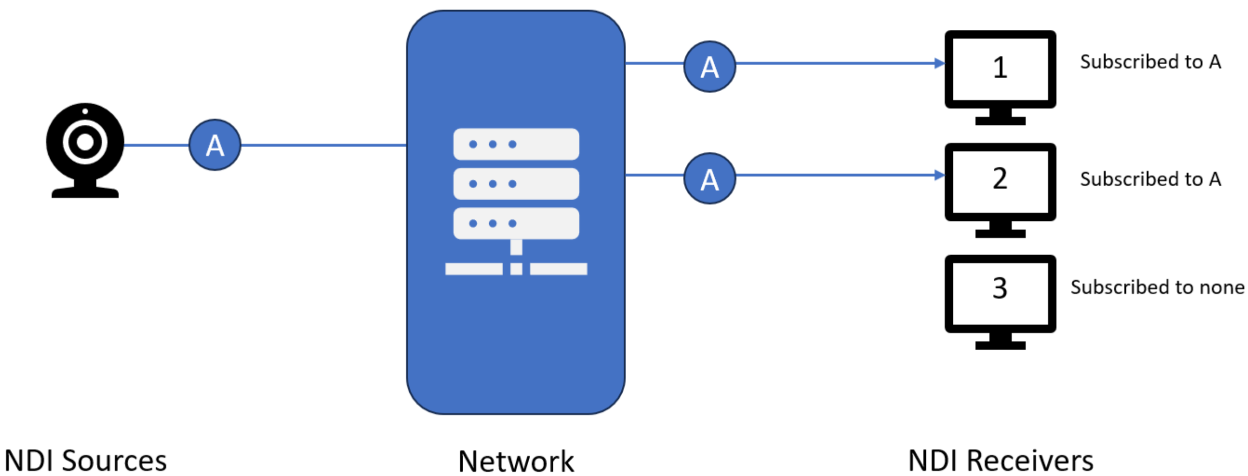

Figure 2 - Multicast Transport

As we add additional sources to the network, individual receivers only receive the streams they are interested in, providing efficient use of network bandwidth, as illustrated in Figure 3.

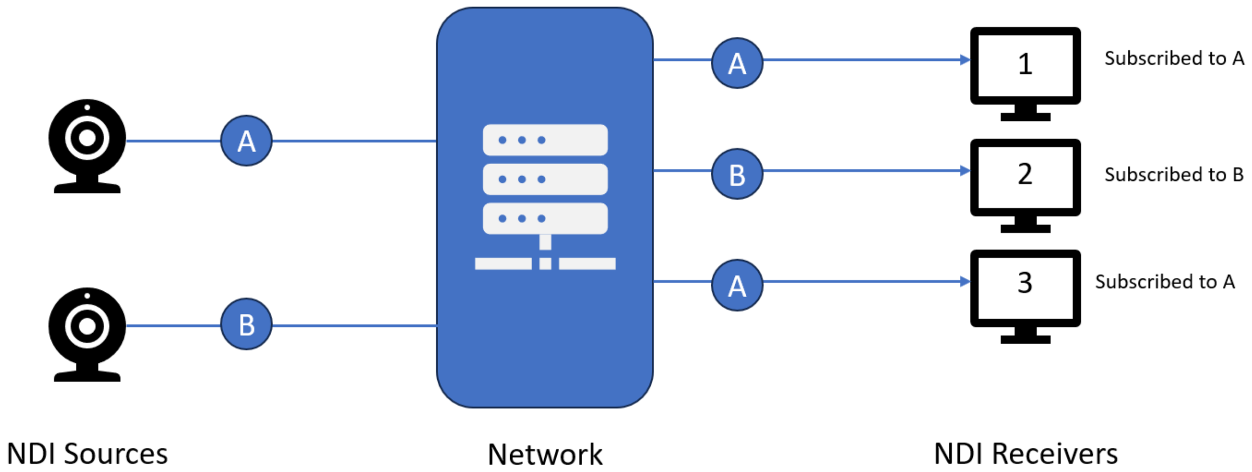

Figure 3 - Multicast with multiple devices

To ensure that a receiver only receives the streams it is interested in, multicast devices use Internet Group Management Protocol (IGMP) to tell the network which multicast streams it wants to receive. This requires the network to have an IGMP querier and implement IGMP snooping. Networking equipment that does not support this (or does not enable it) will typically fall back to a “flood” mode, where all multicast streams are sent to all devices, regardless of whether they want it or not, as shown in Figure 4.

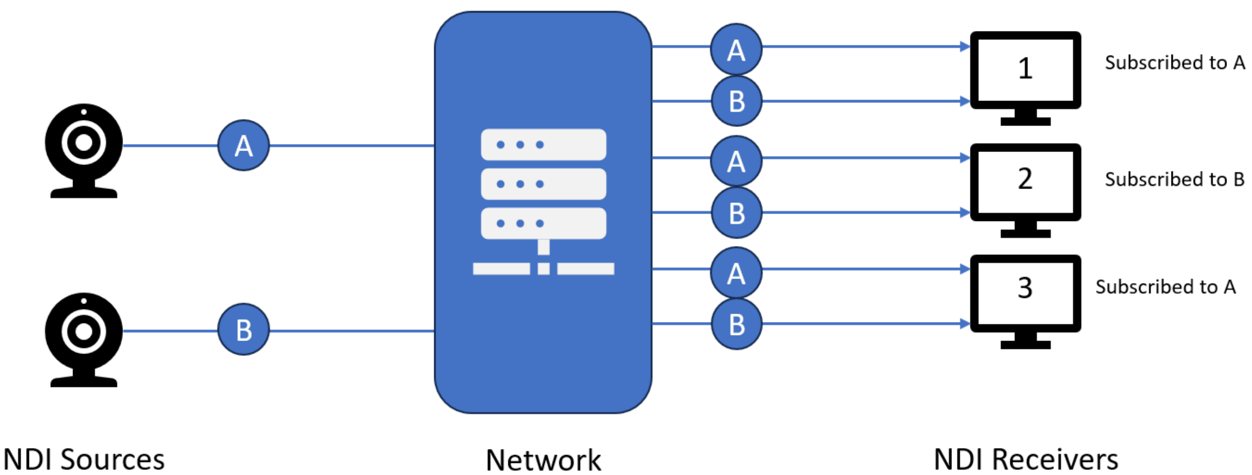

Figure 4 - Multicast port flooding

Multicast flooding can quickly saturate all the bandwidth on a network, bringing it to its knees. Therefore, the network equipment must support proper multicast support with IGMP snooping if multicast NDI streams are being used.

Supported NDI Transport Types

TCP / MULTIPATH TCP

TCP and multipath-TCP are *unicast* transports that guarantee delivery. The receiver must acknowledge each packet; if a packet is lost, the source will retransmit it. This offers high reliability at the expense of large (and unpredictable) latency.
Multipath TCP allows transport across multiple NICs and network paths.

UDP / UDP+FEC

UDP is a *unicast* transport that can be considered “fire and forget.” The source transmits packets, but there is no guarantee of delivery. If the receiver does not receive a packet, it is lost forever and will not be retransmitted. This offers much lower (and predictable) network latency as there are no packet acknowledgments or retransmissions. This is generally preferred for video streaming as a momentary minor glitch is preferable to unpredictable delays in the transmission path.

UDP may also include Forward Error Correction (UDP+FEC). This includes extra information in the stream that allows a receiver to reconstruct a certain amount of information that may have been lost in transmission. This has a penalty of higher latency and bandwidth than standard UDP, but it is more predictable and generally has lower latency than TCP.

RUDP

Reliable UDP (rUDP) is an optimized *unicast* UDP transport that provides dynamic bandwidth and buffering techniques along with sequencing and flow control to optimize delivery over congested and high-latency networks. It is the default transport recommended for most networks.

MULTICAST

Multicast transport utilizes UDP network transport, but rather than being point-to-point as in unicast UDP, it allows one-to-many transport with the lower latency of UDP. Multicast NDI offers the most efficient use of network bandwidth if the network equipment supports it.

Discovery

For NDI receivers to connect to network streams, the receiver needs to discover what streams and devices are available. NDI implements two different mechanisms to facilitate discovery and registration of NDI streams:

- mDNS
- NDI Discovery Service

mDNS

Multicast Domain Name System (mDNS) is a mechanism that can create a zero-configure discovery environment. A device can discover the available services on the network by sending an mDNS multicast message (multicast address 224.0.0.251, port 5353). Discoverable NDI devices reply to the sender using a unicast response, disclosing their available resources.

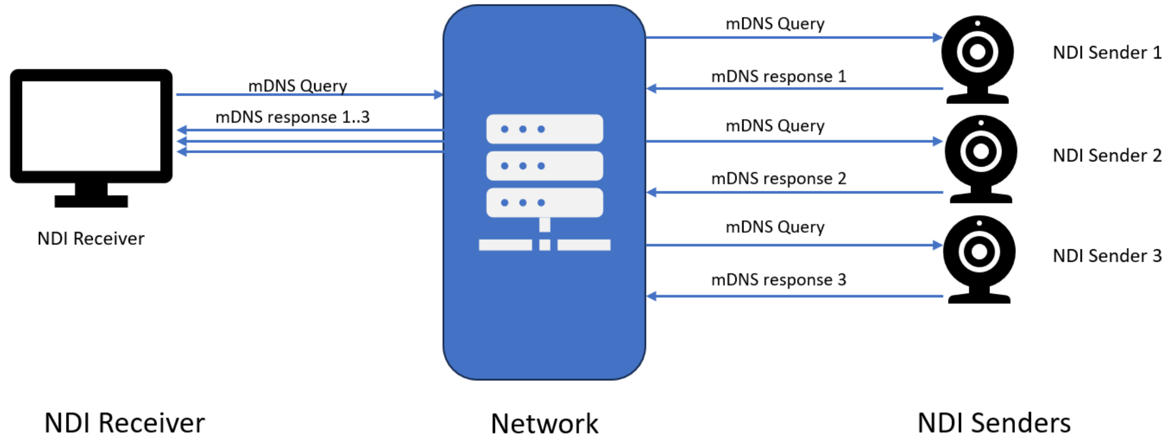

Figure 5 - mDNS Discovery

In simple network environments, mDNS will work without any special configuration. However, it is crucial to verify the following:

- Multicast (including mDNS) will not traverse across subnets unless the network is specifically configured to enable multicast routing.
- mDNS may not traverse across multiple physical switches in a stacked or spine-leaf topology.
- mDNS is not usually supported in cloud deployments.
- Firewalls must be configured to pass mDNS messages.
- In Microsoft Windows, the Network Location should be set to Private.
- mDNS usually does not require multicast snooping to be enabled on a network switch. Simple networks will forward the mDNS traffic to all ports (these are small messages). However, if a multicast querier is enabled, ensure it is configured to allow mDNS (224.0.0.251) messages to be forwarded.

For small NDI installations, mDNS discovery is simple and effective. However, NDI Discovery Server should be used for larger systems or systems with multiple subnets.

NDI Discovery Service

One of the disadvantages of mDNS for discovery is that it is a many-to-many discovery mechanism. Each receiver device reaches out to the network, and every sender must respond to each receiver. This can cause unwanted overhead for systems with a large number of devices. mDNS also relies on multicast, which might be undesirable or unsupported in some network environments (such as some cloud environments, spine-leaf, or Layer-3 routed networks).

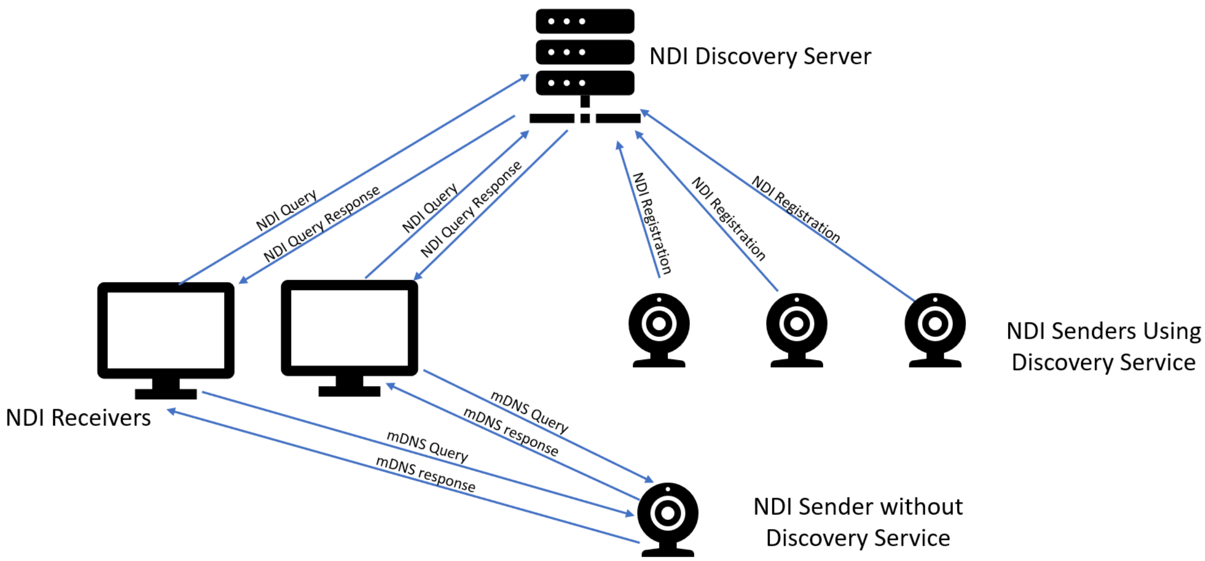

Figure 6 - NDI Discovery Service

The NDI Discovery Service provides a centralized registry for NDI resources on a network. Senders actively register themselves with the discovery server, and receivers query the discovery server for available streams, all using unicast messaging. This can be significantly more efficient and reliable than the mDNS approach, reducing the overhead of many-to-many discovery.

When a sender device is configured to use NDI Discovery Service, it registers itself with the discovery server and will no longer respond to mDNS query requests. A receiver will only learn about these senders via the discovery server. The receiver can still learn of senders which are not configured for Discovery Service through mDNS.
NDI also supports multiple active discovery servers, allowing redundancy and eliminating a single point of failure.

The main downside of NDI Discovery Service is that it requires an additional component to be added to the network. This might be a physical server, VM, or cloud instance.

What Settings Should I Use?

NDI Profile

Although each installation is unique with its own requirements, here are some good starting points:

Each NDI profile offers different advantages:

- NDI High-Bandwidth is the most universally supported, offering low latency with high quality. It is recommended for applications where image quality and latency are the primary concern.
- NDI HX and HX2 offer significantly lower network bandwidth utilization at the expense of latency and quality.
- NDI HX3 provides quality and latency similar to NDI High-Bandwidth at approximately half the bandwidth utilization. However, it is not yet supported broadly.

As general guidance, NDI-HB is used more in live production (such as in studios, sports, or live events), where image quality and low latency are critical. NDI-HX / HX2 / HX3 is more common for remote sources (such as remote PTZ cameras) and more direct-streaming applications. You are also free to mix profiles in a facility (for example, to optimize latency on certain critical signals vs. lower bandwidth on others). However, it is essential to check which profiles are supported by all devices on the network. If you decide, for example, to implement HX3 in your design, you may come across some devices that cannot receive it.

NDI Transport

The NDI transport protocol selection for most users will be one of the following:

- rUDP is efficient for simple networks with few (10's of) devices. It could hit scaling issues, particularly when a single source must be sent to many receivers (such as black or bars). This is the default transport protocol for NDI.
- Multicast provides the most efficient network bandwidth utilization on both sources and receivers. However, it requires specific multicast handling by the network hardware. Multicast can be challenging to configure and troubleshoot and is usually unsupported in cloud environments.

Discovery Mechanism

NDI Discovery Service should be considered if any of the following are true:

- There are a large number of NDI devices (>20 or so) on the network
- NDI devices span across multiple subnets
- Multicast is not supported or undesirable on the network

If none of the above scenarios apply, mDNS peer-to-peer discovery can be used, so setting up an NDI discovery server is unnecessary.
The key reasons to *not* utilize NDI Discovery Service include:

- It requires a server on the network to run this service
- If the service goes down, NDI discovery and connection are not possible (however, the use of redundant Discovery Servers can mitigate this risk)
- All devices must support and be configured to use the Discovery Service. Most modern devices support Discovery Service (and it is a requirement for NDI Certification).

Building Your NDI Infrastructure

There are several factors to consider when building your infrastructure, whether it is primarily NDI-based or uses NDI to supplement an existing solution (such as SDI or ST 2110). We have already discussed some of the implementation technology choices above, but the choices of physical devices, software and networking implementation need to support your implementation goals.
First, consider your network requirements. If you are considering a solution with many devices (more than 20 or so), you should consider a managed network. This can include:

- Managed, non-blocking network switches
- Sufficient uplink bandwidth between switches
- Multicast support, including IGMP querier and snooping
- VLAN segmentation of NDI and other traffic
- QoS to prioritize media traffic

Look to a network vendor with experience working with NDI. When configuring your network, it will save you a lot of time and frustration if your vendor has setup guides or pre-built profiles to support NDI. When you're having issues, you'll appreciate a vendor with knowledgeable tech support.

- When considering hardware and software solutions, ensure they meet your implementation choices, including NDI Profile (NDI-HB / HX / HX2 / HX3)
- Transport type (rUDP, TCP, multicast, etc.)
- Discovery mechanism (mDNS or discovery server)
- Video format compatibility
- Do they implement the latest NDI versions? Are they receiving updates from the vendor?

- Cohesive NDI Environment: Consider adopting solutions from a vendor that offers a broader ecosystem of NDI-compatible products, including routing, switching, graphics, and more. This simplifies integration, streamlines support, and ensures interoperability between different components in your NDI workflow.
- Scalability: Choose a scalable core solution, allowing for expansion as your needs evolve.
- Hybrid Format Support: Consider hardware and software solutions that support a hybrid approach.
  - This lets you leverage the benefits of NDI while also integrating SDI, HDMI, ST 2110, and other formats without needing disparate, discrete format converters.
  - This flexibility allows you to leverage endpoint devices and infrastructures that utilize various standards and physical layers, selecting the best technology to fit workflow, infrastructure, and budget needs.
- Modularity: Consider products with modular hardware architectures that allow the addition and changes to supported signal types and system scale/size as the need arises, protecting your investment for years to come.

One of the advantages of NDI is that many software solutions offer integrated NDI support. However, if this is part of your implementation plan, you should consider:

- Hardware requirements
- Does the application support the transport and profile choices you wish to use?
- What are the limitations of using NDI (for example, is there a maximum number of inputs or outputs it supports?)

NDI devices span a wide range of price, quality and reliability, so choosing solutions from a trusted supplier is also vital.

Conclusion

NDI offers a powerful yet easy-to-use network media solution that can be used in solutions ranging from small installations to large media production facilities. However, it is crucial to understand the underlying technology to make informed decisions about integrating it into your infrastructure. As solutions grow in size and complexity, informed deployment decisions must be carefully made to ensure good performance and reliability.