WAN Design Exercise

Designing Oberoi Community: a smart community

Section 1: Introduction

Continuing the previous LAN design exercise, we assume the existence of 3 Local Area Networks (LANs) for 3 different localities: one for a housing society in Mumbai, one in Chennai and a university (IIIT) in Hyderabad. We assume that all three localities were constructed by the same builder, Oberoi Realty, and this builder is planning to create Oberoi Community™, a smart, well-connected happy community that consists of residential societies as well as educational institutions. Keeping this thought in mind, the builder has constructed these residential societies and a university in Hyderabad, with the university offering premium, world-class education to families living in these societies. In fact, families belonging to the Oberoi Community are entitled to a certain discount at this college, in the hopes that this would lead to more people purchasing homes at Oberoi housing societies and being a part of the community.

Keeping the same thought in mind, the builder after consulting with the residents of the society decides to connect the LANs of these localities to construct a Wide Area Network (WAN). A key reason for this is parents experiencing disconnect from their children due to them staying away for long periods of time in other cities. With the COVID lockdown emphasising the importance of connection, they want to stay connected with their children and involved in their lives, while simultaneously ensuring they receive good quality education. In an effort to solve the above problems, the builder decided to construct a WAN to facilitate high speed communication between parents and their children. After several discussions and meetings with parents, the following use cases were agreed upon:

1. Video communication between parents and children (i.e between Mumbai-Hyderabad and Chennai-Hyderabad), in an effort to remove distance barrier

2. Also, video communication with other parents living in other cities (eg. Mumbai-Chennai), albeit less frequently. This is to forge a community feeling, among parents, allowing them to communicate with people in similar positions as them

3. An option to monitor the academic performance of their children from a commonly accessible portal, so that they can guide or help their children in case of any stress or mental health issues which may affect their performance.

4. An option to spend a good weekend together by live-streaming movies or sports matches on a portal allowing this kind of multimedia streaming and synchronisation. Recreation is, after all, as important as work!

5. Lastly, an option to view and attend live streaming of parent-teacher meets, which are regularly conducted in college and streamed through video sharing platforms such as Zoom or Google Meets.

Apart from these use-cases, from a utilities and disaster management perspective, there are some additional requirements which would be needed by our WAN:

1. We need some kind of online metering for monitoring utility services like electricity, water, LPG gas pipeline connection and sewerage connections.

2. There is a need for the installation of seismic meter, so that locals have the knowledge about the earthquake in advance.

3. Since Mumbai and Chennai are very flood prone areas, with Hyderabad also being flooded recently due to excess rainfall, our network should not be sensitive to environmental damages, particularly rain and floods, and there should also be flood sensors installed to deliver timely warnings to the local municipality.

4. There is a need for customised smoke detectors, which are directly connected to the fire brigade office.

5. There should be surveillance cameras set up to detect intruders, which have a direct connection to the nearest police station.

Additionally, since the Oberoi community mostly consists of upper-middle class residents, the focus of the network should be on Quality of Service, speed, fault-tolerance, safety and reliability.

These use-cases can be formally translated into the following requirements, namely:

1. Should have high speed and high bandwidth
2. Since one of the key use cases is real-time streaming, there should be minimal latency and high throughput. Loss of data should also be minimal
3. Should be resistant to environmental damages, particularly rain and flooding
4. Localities are situated in major metropolitan cities, and subjects are well-to-do, indicating higher budget and less compromise on Quality of Service (QoS)
5. Different localities can have different rates of traffic, and the network should be optimised to deal with that
6. In case of the network involving disaster detection sensors, there should be very low latency, though high bandwidth is not required.

In the following sections, we first proceed to describe, in detail, the WAN options used for connecting localities located in different cities and elaborate on the reasons for our choices. Then, we proceed to describe the installed meters and disaster management sensors, mention our reasons for selecting them and then elaborate on the options chosen for connecting the LAN to various departments, thus creating a MAN.

Section 2: MPLS - Interconnecting LANs from different cities

In order to connect LANs from Hyderabad, Mumbai and Chennai we use Multi-Protocol Layer Switching (MPLS), as described in Figure 1. The reasons for this, keeping in mind our requirements and our use case are described below [1][2][3]:

1. **Improved bandwidth:**
   - **a)** MPLS divides the traffic in various networks which means the bandwidths of our network will automatically increase.
   - **b)** Multiple traffic types, be it Hyderabad-Mumbai live streaming or Mumbai-Chennai video conferencing, can thus transverse through the whole network in very little time.
   - **c)** This is very much unlike the older frame relay or WiMAX that scales badly, and results in poor bandwidth when serving multiple people simultaneously

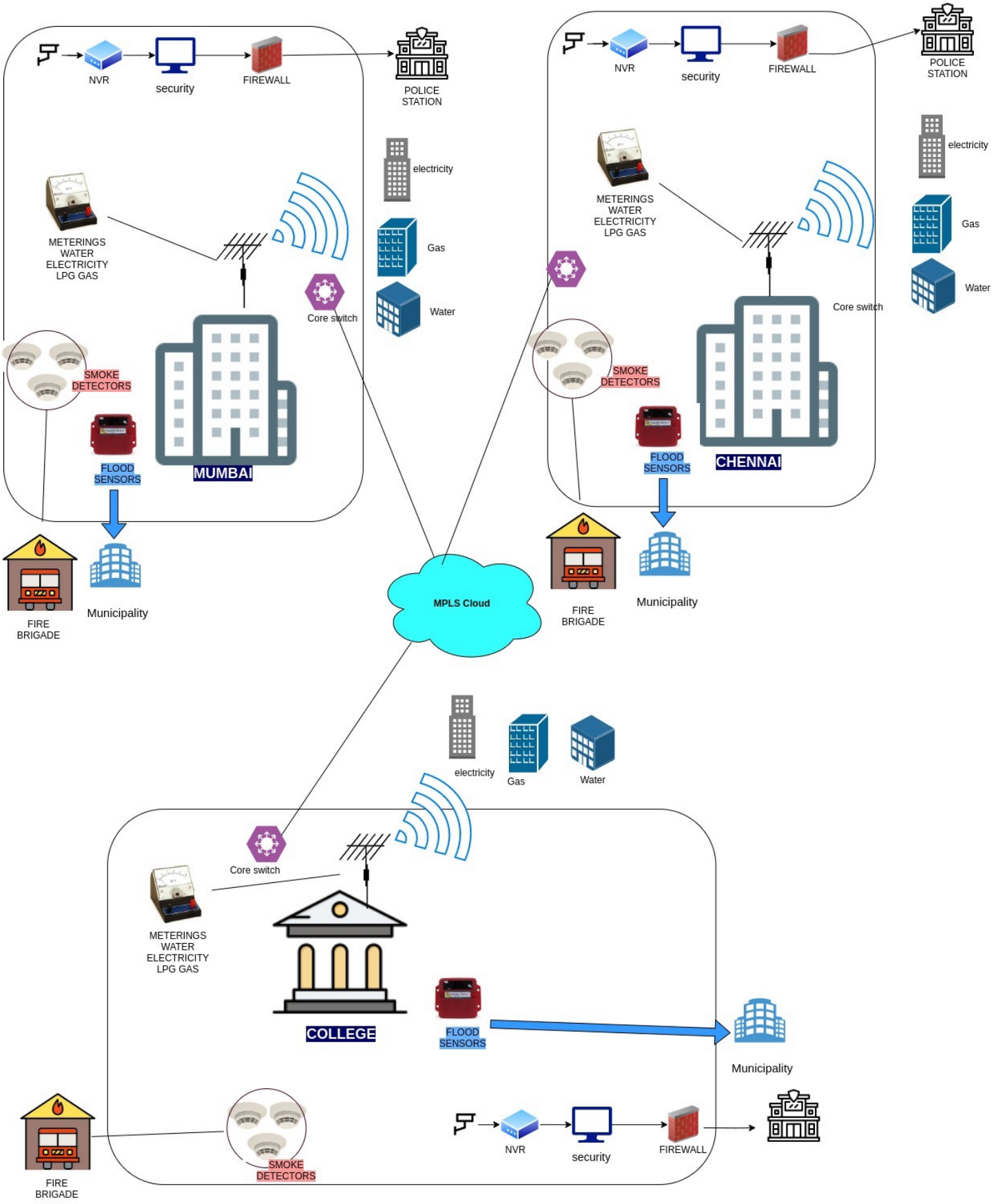

Figure 1: Oberoi Community: WAN connecting localities in Mumbai, Hyderabad & Chennai. Note: Lines connecting sensors and utility providers represent Cat6 Ethernet cables.

2. **High Quality of Service:**
    a) MPLS allows multiple Classes of Service to different types of traffic, thus allowing certain types of traffic to be prioritised during congestion.
    b) Users can thus specify jitter, latency and packet loss minimum thresholds for each type of traffic (voice, video, email, large file transfers, etc.).
    c) This means that the MPLS network would treats latency-sensitive traffic, like real-time streaming of Parent-Teacher meetings or watching live matches, preferentially over less-sensitive traffic, like viewing the online results portal.

3. **Better network performance:** MPLS provides various alternate network paths to a request and divides the requests in various network paths, thus significantly improving uptime and reducing traffic congestion respectively.

4. **Better Traffic Routing and Reliability:**
    a) Since MPLS works by adding labels and using them to direct packets down a pre-determined path, its much faster and more efficient than normal technology that time-consumingly uses IP header information to read and determine paths.
    b) This also helps in improving the reliability of MPLS, since packets travelling down pre-determined LSPs (Label Switched Paths) makes it very easy to predict the traffic of a network. Contrarily, in IP routing the path of the packet can differ according to the network conditions severely affecting reliability.

5. **Delivery Guarantee:**
    a) MPLS services are delivered with Service-level Agreements or SLAs, which basically ensures guarantees from the carrier when it comes to installation times and availability.
    b) This is in contrast to broadband or Ethernet, which is typically offered on a best-effort basis.
    c) Crucial to real-time streaming and live conferencing

6. **High Scalability:**
    a) It is very scalable and allows the network to grow, change, or be reduced without purchasing new hardware or procuring additional WAN circuits
    b) This is really necessary when Oberoi Community grows, and additional societies/universities are built which need to be added to the WAN network.

MPLS thus guarantees improved efficiency due to better QoS and bandwidth handling, while simultaneously ensuring low resource wastage. It offers delivery guarantees for time-critical data, reliability and is also more resistant to environmental damage than other network options. In addition, it is highly scalable and ensures easy-addition/removal of networks with the growth of the community.

Thus we create a WAN by interconnecting the LANs of Mumbai, Hyderabad and Chennai using MPLS technique.

Section 3: Firewall

To protect LAN of each of these localities in the WAN against external traffic, we use Next-Generation Firewall. The benefits of using such a firewall are multifold [8][9]:

1. It is a combination of traditional packet filtering firewall technology with additional functionality, such as encrypted traffic inspection, intrusion prevention systems, anti-virus, and more.
2. Most notably, it includes deep packet inspection (DPI). While basic firewalls only look at packet headers, deep packet inspection examines the data within the packet itself, enabling users to more effectively identify, categorize, or stop packets with malicious data.
3. We don't need to monitor and maintain it regularly because it automatically gets upgraded.
4. Unlike traditional firewall, next-generation firewall ensures consistent throughput irrespective of the number of devices and security protocols. This is necessary in large societies and complexes like those in Mumbai and Chennai.
5. Most importantly, next generation firewalls have an inherent ability to detect user identity. It can also work with different user roles and limit the scope of access for an individual and/or group. This particularly is useful in our use case because it can be used to guard the internal data of our society LAN (such as the data exchanged with grocery/pastry shop) and provide access to other data.

Section 4: Meters - Gas, Water, Energy

Services	Mumbai	Hyderabad	Chennai
Police station	4km	4.7km	6.9km
Fire department	6km	2.9km	2.2km
Municipality branch office	4km (BMC)	4.2km	7.3km (Greater Chennai Corporation)
Earthquake detection center	22.4km (IMD mumbai)	5.5km(EERC)	20 km (IMD Chennai)
Power distribution company	5km (Adani power)	13.5km(TCPDCL)	24.4km (power-grid corp. of India-substation)
Gas distribution company	3km	4.3km	5 km
Water distribution	12km	8km	15km

Table 1: Distances of various Disaster Management departments and utility providing services from localities in Hyderabad, Mumbai and Chennai.

Online metering and monitoring of utility services is called smart-metering and it is closely linked to Internet of Things (IoT). LECSIndia [5] offers products that do the smart metering for water, gas and energy and establishes a full duplex connection (for sending data and receiving confirmation) between the metering device and the utility providers' network. The products offered by LECSIndia include:

1. **Optical port:** Although fast, it is very expensive. Investing in fibre optic just for gas, water and electricity readings (which are in the order of a few KB) is impractical.

2. **GSM/GPRS modems:** This would be a good option for a single household, but fitting this in each home would require the purchasing of a separate modem for each household, which is expensive.

3. **RF interface:** This is chosen for the following two reasons:
    1. All residents have their sensors connected to the same antenna, therefore they can pool their resources and have a shared antenna per tower
    2. The antennas for water, gas and energy sensors can cover the distances to the respective water, gas and power distribution companies easily. We prove this claim below.

We know that, Hyderabad Building height > 15m, Mumbai Building height > 50m, and Chennai building height > 80m. According to antenna coverage formula:

- Range of antenna = 3.577 * sqrt(antenna height in meters)
- Hyderabad tower: 3.577*sqrt(15) = 25km > max(5,3,12) = 12km
- Mumbai tower: 3.577*sqrt(50) = 25km > max(5,3,12) = 12km
- Chennai Tower: 3.577*sqrt(80) = 32km > max(24.4,5,15) = 24.4km

This shows that the antenna is sufficient to cover the necessary distances in all 3 cities.

Frequency wise, RF interface comes in two models: **RF 443MHz** and **RF 2.4GHz.**

We opt for the higher bandwidth solution because

1. Since this is shared by all, we can choose the more expensive option as all residents will share the cost.
2. Since the towers are tall , we assume more people require service, therefore greater bandwidth is required.

To conclude, the three utilities can be metered by the company lecsindia, and the mode of communication to the respective companies can be done via, antenna (Radio Frequency 2.4GHz).

Section 5: Sensors - Intrusion, Flood, Smoke

Section 5.1 Intrusion Detection Surveillance System

The surveillance technology we will use is NVR - network video recorder. In such a setup, there are surveillance cameras that stream footage into the NVR. A security guard monitors all the surveillance cameras from the control room, and on detecting an intruder, he sends a signal from his terminal to the police department and this transmission is carried out by Ethernet cables.

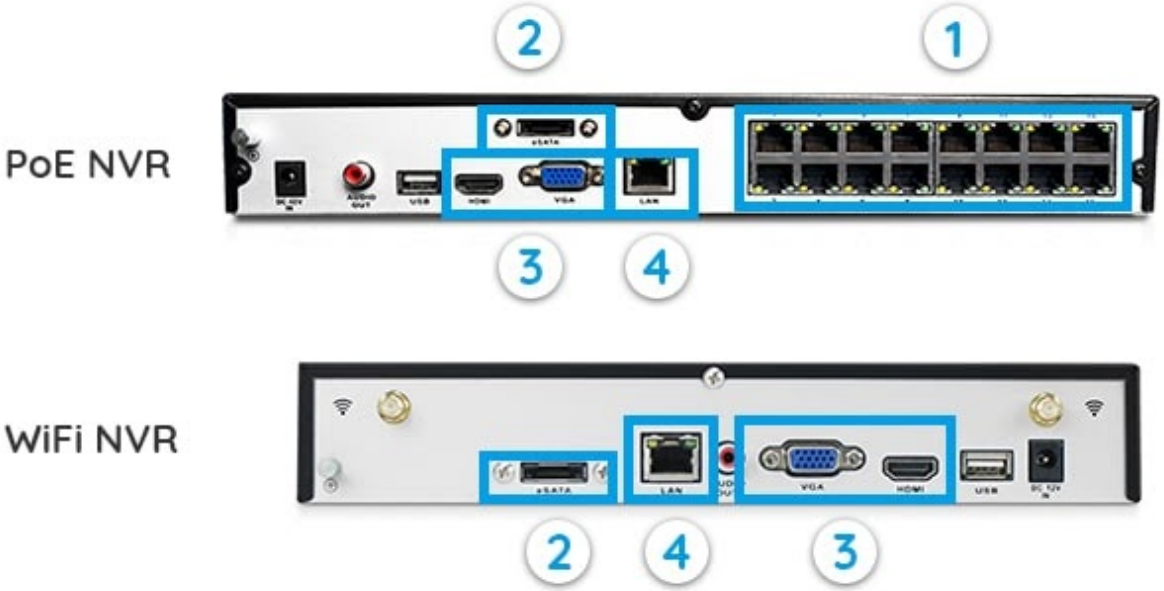

Figure 2: PoE NVR vs WiFi NVR

We use PoE NVR over WiFi NVR so that the cameras are supplied power through the network cables *(power over Ethernet)*, hence ensuring no additional cabling cost. It also provides upto 10x coverage as compared to WiFi NVR, has faster transmission speed, more reliability and is less susceptible to hacking than WiFi NVR [7].

The 16 ports shown in the Figure 2 means that it is a 16 channel NVR and can connect to 16 cameras.

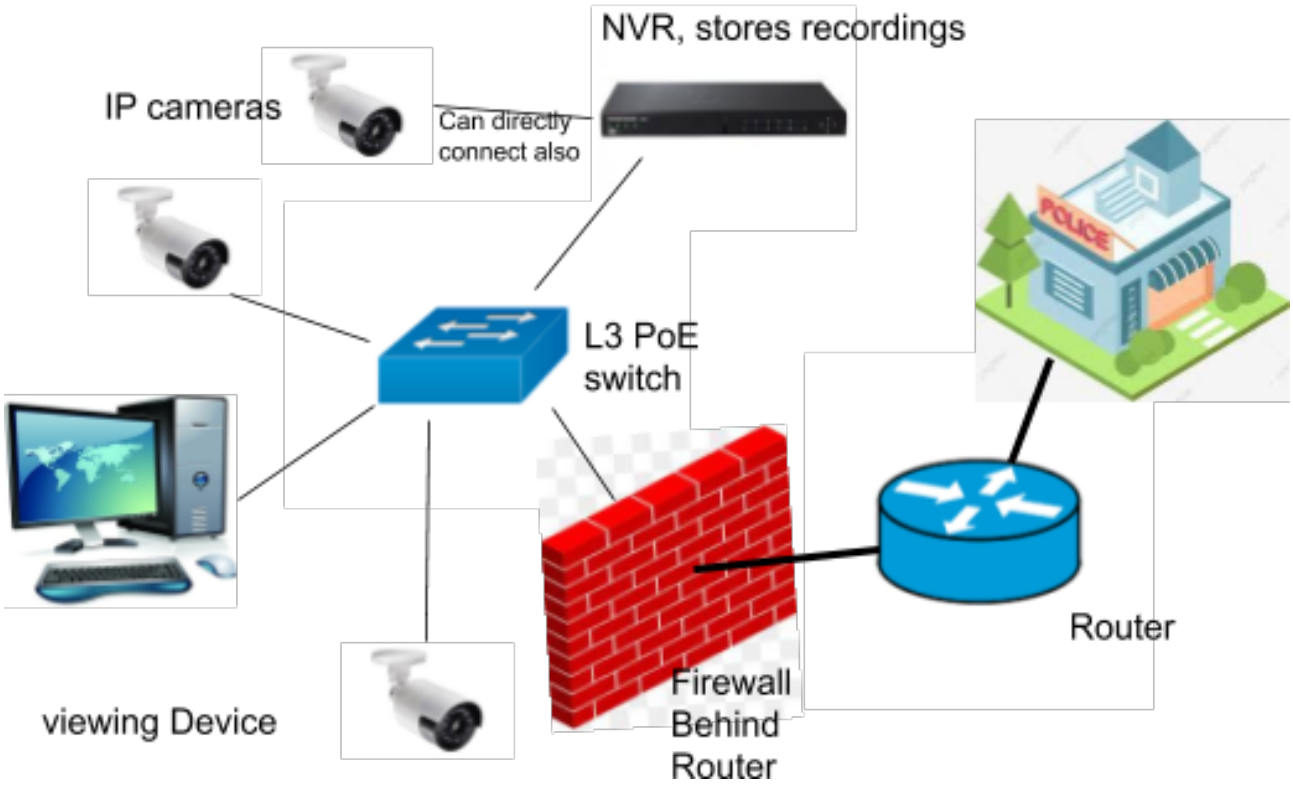

Figure 3: Sample diagram showing working of NVR

Kintronics [6] offers 3 solutions for implementing NVR: . exacq, Hanwha, and CyberShield-NVR. Since our choice is a PoE NVR design, we look at how many ports these NVR's have:

1. **Exacq's G Series:** Has two models: a 4 channel and an 8 channel NVR, storage options range from 1TB to 6TB
2. **Hanwha:** contains 16 PoE ports
3. **CyberShield-NVR:** This enhanced network video recorder is an all-in-one appliance with a server, storage and managed PoE switch. Models include 8 channel, 16 channel and 24 channel NVRS.

The third option is most desirable for our case as it can hold 24 cameras, and for 8 towers in total, can support 3 cameras per tower. We prefer the CyberShield-NVR-Pro model over the enterprise model.

For greater security, we place the cameras on a separate network from the rest of the LAN, as shown in Figure 4.

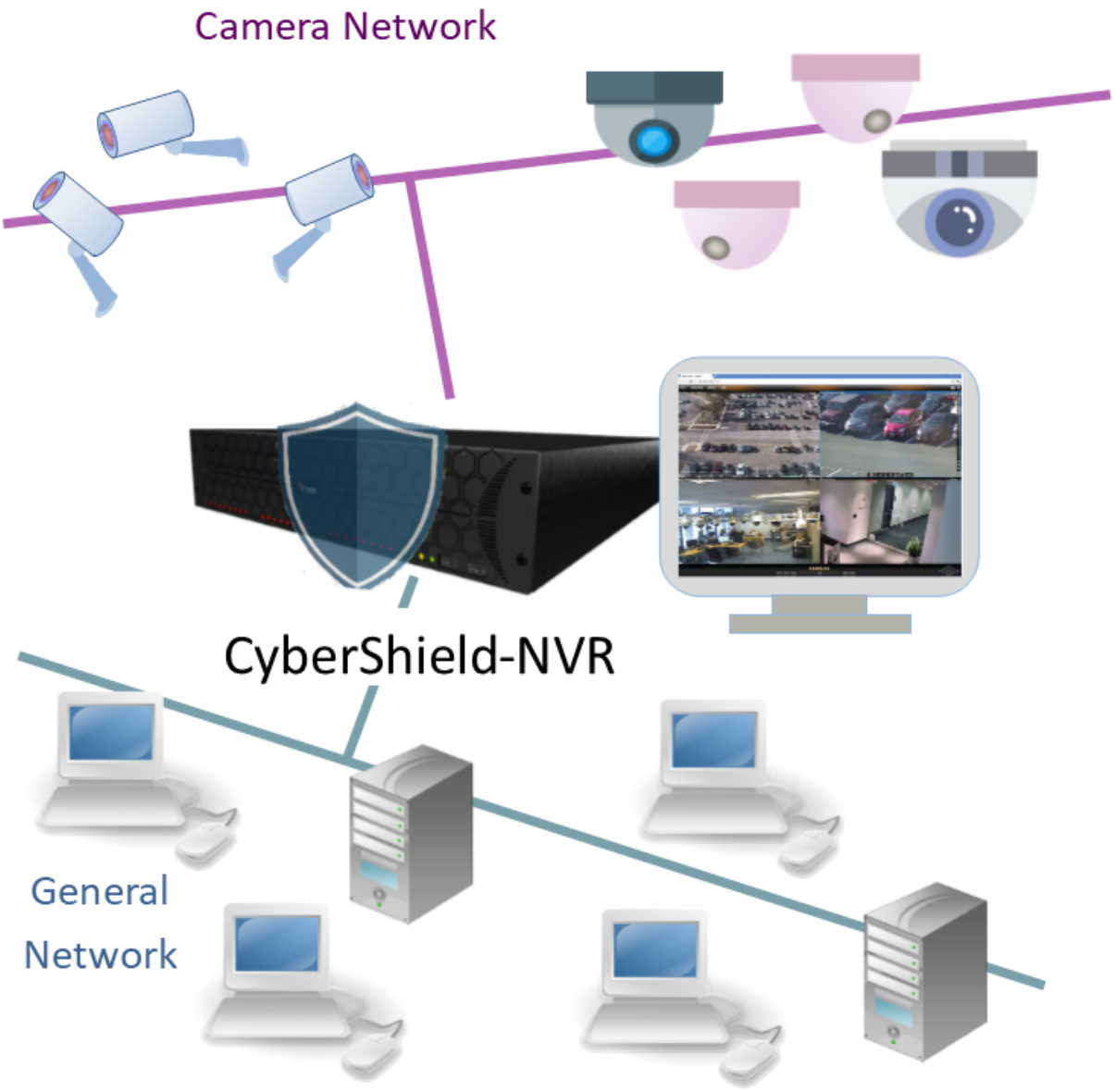

Figure 4: Diagram showing the placing of NVR wrt the general network

The connections (camera-NVR) aren't temporary, like most wireless connections. In addition the number of cameras are limited, so their mac addresses can be exploited for improving security, i.e binding them to ports. This separation allows us to closely monitor traffic in the camera-NVR network.

We do this separation for the following reasons:

- Since the cameras are in physically remote locations, someone may disconnect the camera and connect their device physically to gain access to the network, hence binding the mac address to a port will detect a change in device.

- Another practical reason for separating the cameras from the main network is to avoid the bandwidth on the main network being eaten-up by the camera footage traffic.

Section 5.2 Flood Alarm

To detect water levels and control floods, we use Proteus AQUO - WiFi Water Detector [10], which has the following significant advantages [11]:

1. Easy to setup. Can be set up by someone who has limited knowledge of computers or the internet by running directly on web browser
2. Sends email and text notifications in case it detects presence of water in any location, any floor or surface
3. No batteries needed
4. Sends a notification when there is power loss
5. Sends a warning when the device has not reported for a while to protect against device becoming faulty

This flood sensor is installed in the ground floor of every tower and is configured to send notifications to the IMD (Indian Meteorological Department) through the Ethernet cable.

Section 5.3 Smoke Detector

We install smoke detectors in our apartments and the coordinating node in this network will connect to the nearby fire brigade. This process will be automated. We now have to choose between wired and wireless (battery operated) smoke detectors.

1. **Wired**: The advantage of wired detectors is that we don't have to worry about recharging, but few disadvantages are:
   a. Its hard to extend network of smoke detectors, because cabling would be required after every new addition
   b. Cables are at risk of catching fire.

2. **Wireless**: While these require batteries, they are overall advantageous because:
   a. Very easy to extend the network of smoke detectors, possible to create a mesh-like network
   b. No cabling involved, so no wires are at risk of catching fire.

In our system, each house contains one smoke detector, and connects to its neighbours on the same floor. This way both connectivity will be ensured (fire in one apartment will alert all neighbours) and the costs of maintenance will be borne by individual members. As new people move into the apartment, they can buy their own smoke detector and link up with their neighbours, this will not involve the hassle of cabling.

We use a mesh topology to interconnect these sensors since this way, there is no single point of failure and in addition, wireless connection ensures that there is minimal extra cost of making new connections.

Section 6: Transmitting data from sensors

In order to connect sensors to the relevant departments, we use 10 Mbps Metro Ethernet connection. This is done for the following reasons [4]:

1. **Performance:** Ethernet offers low latency and high-throughput, which is ideal for disaster recovery. Low latency also ensures minimal time delay while relaying the warnings of sensors and/or meters, which is ideal for our purpose.

2. **Cost:** Ethernet is typically more affordable than MPLS or Leased Line, and is one of the major reasons for our choice. We typically do not need high bandwidth offered by MPLS/Leased Line since our sensor data will be in the order of a few KB, and no voice/video streaming will be taking place.

3. **Delivery Guarantees:** IT professionals can ask SLAs (Service Level Agreements) for their Ethernet service, thus guaranteeing delivery of sensor data.

4. **Weather resistant:** While it does not offer as much environmental protection as optical fiber (which is very expensive and an overkill), shielded waterproof ethernet cables with water proof connectors come very close to providing tolerance to environmental factors, particularly rain and floods which are common in Mumbai, Hyderabad and Chennai. It is also much more water resistant than most wireless connections which can potentially suffer from rain fade.

References

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