

PREDICTIVE VIDEO AWARE NETWORK FOR REAL-TIME VIDEO TRANSMISSION OVER CELLULAR NETWORKS - WHITEPAPER

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1. BACKGROUND

To truly enter the digital age and become smart cities, municipalities need to install thousands of video cameras. This, alongside with recent advancements in video analytics (VA) and artificial intelligence will shape the smart-city in the coming years.

The video stream from each camera is transmitted to a control center (or to the “cloud”) to be viewed in real time, recorded for later viewing, and analyzed by VA systems.

In 2017, 10 million cameras were installed worldwide for safe and smart city applications. Most of these projects (over 90%) involved cumbersome, expensive and non-flexible cable installations: using cables to connect the cameras to the city high-speed-backbone (80m of cabling on average, AKA the “last mile gap”) and to the control-center. By 2025, the number of camera installations (only for safe and smart city applications) will grow to 35 million per year, with an annual growth rate of 23%, reaching 100 cameras per Km².

To answer the above need for today’s and tomorrow’s rapidly changing cities, an **immediate, flexible, and cost-effective solution for connectivity of thousands of cameras is a must.**

This can only be done using the cellular network. However, due to the limited bandwidth as well as the varying nature of the cellular network, together with the bandwidth requirements of high-definition (HD) video, the cellular network cannot support camera connectivity – both in current 4G networks as well as in the upcoming 5G networks.

Telicomm enables camera connectivity over the cellular network, allowing to connect thousands of city cameras in a single day.

2. TELICOMM’S TECHNOLOGY

A. Overview

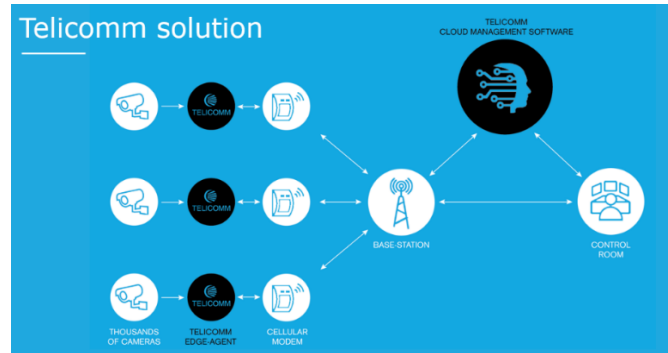
Telicomm’s unique P-VAN™ (Predictive Video Aware Network – patent pending) technology utilizes machine learning combined with signal processing algorithms to allow video transmission from all connected cameras over the cellular network in an optimal and robust way. This is done by predicting – in real-time and ahead of time –

the behavior and needs of all video streams captured by the cameras, together with the condition of the cellular network, and using unique signal processing algorithms to fit all video streams into the currently available network resources.

The solution is comprised of two entities:

Edge-Agents: Connected between the camera and the cellular modem. Perform sensing, processing and control in both video and wireless domains.

Cloud Management Software: Performs the whole system management by utilizing information from all Edge-Agents to gear the P-VAN™ algorithm.

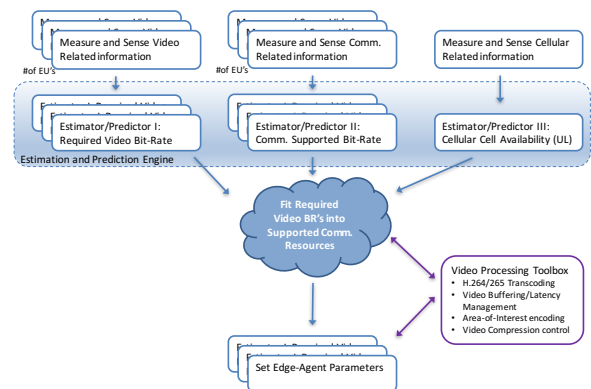


Telicomm's solution enables connecting 20-30 HD-cameras over a single cell of 4G cellular infrastructure in a robust way (compared to 2-3 cameras with current technology), answering the need of the municipalities. These numbers were validated both by extensive simulations as well as demo system.

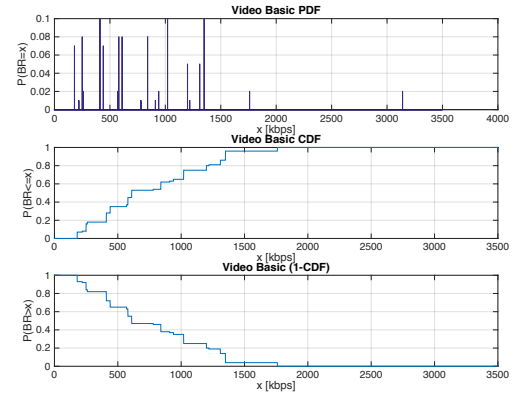
B. Telicomm's novel approach

While competing solutions **take for granted the limited cellular bandwidth** and either significantly reduce video quality (and rate) in order to fit the video into the network, or altogether construct a new dedicated communication infrastructure, Telicomm takes a **unique stochastic system approach allowing to break through the boundaries of limited cellular bandwidth**.

Following this approach, three stochastic processes are measured, analyzed, modeled and predicted in real time:



- i. **Video streams requirements:** When using variable bit rate (VBR) compression, the video bit-rate varies with time depending on the “richness” of the actual scenes captured by the camera. Stochastic properties of 1080p/30fps smart-city HD video bit-rate using H.264 compression is given. Although momentary bit-rate may go over 3Mbps, average bit-rate is around 320kbps.



- ii. **Supported communication data-rate for each camera connection:** Due to the varying channel conditions (e.g. fading, interference, mobility etc.) as well as cellular management rate-selection and control mechanisms, the momentary supported bit-rate over each cellular link varies with time.
- iii. **Overall communication network resources:** Due to existence of other users over the cellular network, the overall resources available for video transmission varies with time.

By measuring real-time values of each of the above, and generating an up-to-date stochastic model for each process, it is possible to predict future values of each of these processes. When dealing with real-time video, prediction is a must to guarantee robust transmission of all video streams given the varying nature of both video and communication conditions.

While measurements are done mostly at the edge, analysis, modeling and prediction are done in real time by a centralized machine learning management engine.

Next, a fitting optimization problem shall be solved: How to fit all required video into the available network resources in an optimal and robust way.

Notice that in some cases, when the momentary video requirements are too high, or the momentary supported network resources are insufficient, there may be no simple solution to this problem. In these cases, video processing techniques must be applied on some of the video streams. Application of these techniques (e.g. buffering, transcoding, area-of-interest encoding, multi-level transmission etc.) depend on the momentary conditions as well as video-management-system (VMS) and user requirements set for each stream.

Using accurate analysis, modeling and prediction in both video and communication domains, performing required video processing algorithms and solving the fitting optimization problem - a predictive video aware network is constructed which guarantees transmission of all video streams by the cellular network in an optimal and robust way.

C. Towards 5G

Although new 5G cellular standard opens new frequencies and increases overall bandwidth, it does not improve significantly enough the uplink rate required for camera connectivity. This was validated both by detailed study of the new standard as well as extensive discussions with multiple 5G leaders: Nokia, Ericsson and others. Furthermore, due to increased camera resolution and higher number of users and applications, **the bandwidth limitation will remain in 5G networks.**

On the other hand, since 5G significantly improves the robustness and reliability of the network, many customers will prefer to connect IoT, sensors and cameras over Cellular.

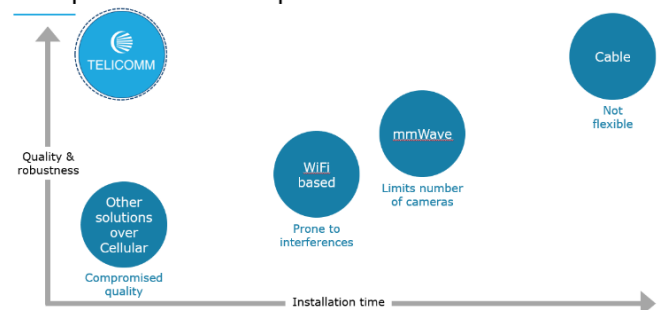
As Telicomm's P-VAN™ technology is readily adaptable to 5G networks, **this opens a huge business opportunity for Telicomm's technology: once 5G is there, Telicomm will solve the video connectivity over 5G.**

3. ALTERNATIVES

Current market state-of-the-art is given in the following figure.

Direct competition includes **other solutions for video connectivity over cellular**. These solutions (e.g. from Surf Solutions www.surfsolutions.com, Zepcam www.zepcam.com and others) utilize local video compression to fit the video into the limited cellular bandwidth, resulting in poor video quality unacceptable for smart-city applications.

Competitive landscape



For projects where time and flexibility are of lower priority, other complementing solutions such as Cables, mm-Wave and WiFi-based may be used. All these solutions require installing dedicated infrastructure. Each is detailed below:

Cables: In spite of the cumbersome, expensive, and non-flexibility of these solutions, cable installations account for over 90% of current smart-city camera installations and are expected to remain a major solution, complementing Telicomm solution for projects where time and flexibility are of lower priority, mainly due to their robustness and reliability.

mmWave: Solutions developed to allow high speed wireless backhaul and internet connectivity for buildings, operating at a radio frequency of 60GHz-70GHz and supporting up to 1Gbps (e.g. Siklu www.siklu.com). For camera connectivity, this is a huge “overkill” (a single camera requires 3Mbps at most) on the one hand, and an expensive and cumbersome solution (requires installation of special antennas with line-of-sight planning limiting the number of cameras) on the other hand. Although

connecting a single camera using this technology costs around \$2,500, it is used today in some cases where cable installations are unacceptable.

WiFi-based solutions, often with some MAC and/or RF/Antenna based enhancements to allow outdoor operation in urban environment (e.g. Radwin www.radwin.com, Ubiquity www.ui.com) are sometimes used for camera connectivity. These systems require dedicated costly installation and lack robustness due to the use of unlicensed band susceptible to interference. These solutions are usually unacceptable for smart-city applications.

4. SUMMARY

To answer the need for today's and tomorrow's rapidly changing cities, an immediate, flexible, and cost-effective solution for connecting thousands of cameras is sought.

This can only be done using the cellular network. However, the cellular network cannot support camera connectivity – both in current 4G networks as well as in the upcoming 5G networks.

Telicomm's solution is the only one that enables real camera connectivity over the cellular network allowing immediate installation, total flexibility, full scalability and dramatic cost reduction providing tremendous value to the city, the integrators and telco companies.

By enabling camera connectivity over cellular networks, **Telicomm's ground-breaking solution will disrupt the smart-city camera market, allowing to connect thousands of city cameras in a single day, answering the needs of today's and tomorrow's smart-cities, and will shape the future of smart-cities worldwide.**