Secure Targetable Digital Television Datacast

An Existing National Network for Broadband Public Safety Communications

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Abstract — **Digital Television (DTV) datacast has proven [1] to be a low-cost long-term sustained technology to push secure video, voice and data to public safety and emergency responders over a wide area. It benefits from being independent of cellular or land mobile radio networks, so does not suffer quality degradation no matter how many video subscribers are capturing data while offering a highly resilient transmission medium. To date, this technology has been envisioned as a regional or statewide capability. However, as the capability is embraced across the country, a national concept of operations (CONOPS) is necessary to ensure the most efficient and effective use of this available broadband medium for information sharing. This paper presents a description of secure targetable DTV datacasting (STDTVD) supported by the Public Broadcasting Service (PBS). It also presents elements of a nationwide STDTVD CONOPS to support local, regional, statewide and national information-sharing needs. The CONOPS addresses STDTVD for all local responders, expanding the number and discipline of users authorized for access as an incident or event grows over time in geographic area and public safety risk. We also describe our ongoing research for STDTVD technology enhancements to optimize data transfer in the diverse broadcast environments encountered nationwide.**

Keywords-broadband, digital television, datacasting, emergency communications, public safety communications, public safety broadband, Public Broadcasting Service, PBS.

I. INTRODUCTION

A. *Purpose and Objectives*

There is an existing resilient and underutilized nationwide communications infrastructure capable of providing secure high-definition (HD) and other video, imagery, audio and data files – any content that can be carried by Internet Protocol (IP) data packets - to selected (targeted) low-cost commercial off-the-shelf (COTS) receivers for law enforcement, public safety, emergency management and disaster response operations. This infrastructure is completely independent of all cellular and land mobile radio (LMR) systems and therefore does not suffer the congestion or disaster-survivability vulnerability of these networks. In addition, this infrastructure is already financially sustained by a well-established commercial and public business model, broadcast television. Recent national disasters in the United States and Japan showed the resiliency of broadcast television infrastructure at times of significant disruption. In those cases, the broadcast infrastructure remained intact and operational throughout these incidents, while mobile services were severely degraded, overloaded or otherwise inoperable.

Japan uses Integrated Services Digital Broadcasting – Terrestrial (ISDB-T), also known as 1seg. 1seg, which allows reception from broadcast towers directly on enabled smartphones and tablets. 1seg was used during the earthquake/tsunami to provide early warning and then post incident information to the public. Even though the cell network was largely compromised, broadcast stations continued to operate on backup power and citizens charged phones in their cars to continue to receive news broadcasts, shelter information and other live updates.

Superstorm Sandy, a more recent U. S. disaster, caused similar communications failures. Flooding and power outages largely compromised the cell and public safety radio systems in southern New York and Northern New Jersey. Television, however, was mostly unaffected due to back up power and redundant systems. Unfortunately, we do not yet have mobile television public alerting to cell phones and public safety secure data distribution in this country but, as this paper suggests, the infrastructure supports this capability.

The paper describes the technology that enables this capability and how we propose its nationwide use for local, regional, statewide, and national critical communications.

B. What is Secure Targetable DTV Datacasting?

All television (TV) broadcast in the United States uses digital transmission of Moving Picture Experts Group (MPEG) transport stream packets to receivers within their coverage area. For standard television broadcasts, that receiver is a television set. Secure datacast receivers are available that can be connected to computers or appliance devices.

Much of the geographic area of the U. S., and about 98% of the population, is capable of receiving over-the-air broadcast digital TV (DTV) transmissions from stations or their translators (i.e., DTV repeaters). The transmitted MPEG packets include Packet Identifiers (PIDs) that distinguish DTV programming guide and video/audio information to these receivers. Many stations can, and do, use less than the 19.39 Mbps in their digital transmission stream, thus creating empty, or null, packets that are ignored by public DTV television sets. Datacasting is the process of inserting IP (computer) data into these null packets for transmission along with the standard television programming. Any digital information that can be created on a computer, (e.g., pdf files, Microsoft Office documents, spreadsheets, briefing slides, digital video, audio, etc.) can be inserted and transmitted within the television broadcast signal with no modification whatsoever to its licensed spectrum or RF equipment.

SpectraRep, LLC, has developed technology to (i) direct (or target) datacast transmissions to specific receivers or *pushgroups* [2] of receivers; (ii) encrypt datacast IP packets using the 256-bit Advanced Encryption Standard (AES); (iii) employ packet content utilizing the current Common Alerting Protocol (CAP) standard; and (iv) provide transmit and receive human-system interface (HSI) through their IncidentOne application to streamline selected and end-to-end-encrypted targeted datacast transmissions to particular pushgroups. We have dubbed this datacasting refinement as secure-targetable DTV datacasting (STDTVD). A single-station STDTVD system with subscribers is depicted in Fig. 1.

In the figure, STDTVD content is aggregated at the Operations Center and pushed to the DTV station, where the encrypted content is merged into the normal station transmit stream. Existing two-way networks such as cellular or LMR can be incorporated to provide a return path enabling bidirectional communication. The return path can be narrowband, even the data path of Project 25 LMR equipment, if all that is needed is content receipt acknowledgement. Using two independent networks in this way is similar to the way early cable modems worked (i.e., phone line upstream and cable broadband downstream).

As shown in Fig. 2, an IP encapsulator inserts encrypted IP packets into the payload of the broadcast MPEG transport packets. Fig. 3 illustrates IP packet payload substitution in the MPEG transport packet. The MPEG transport wrapper is unchanged, allowing these IP packets to pass through the television station physical plant and transmitter for datacast. The MPEG transport Packet ID (PID) is used to identify the

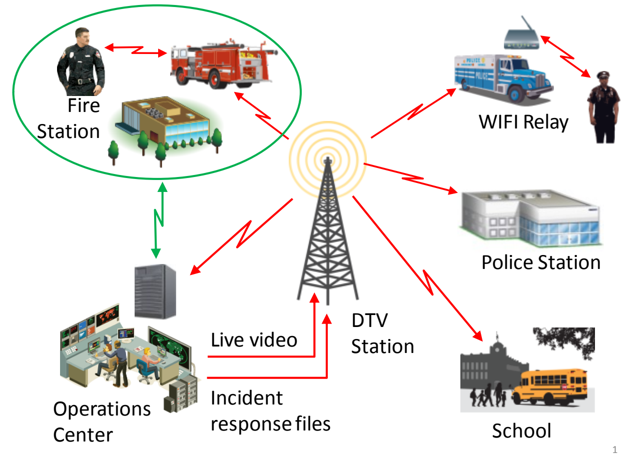

Figure 1. Single-station STDTVD system.

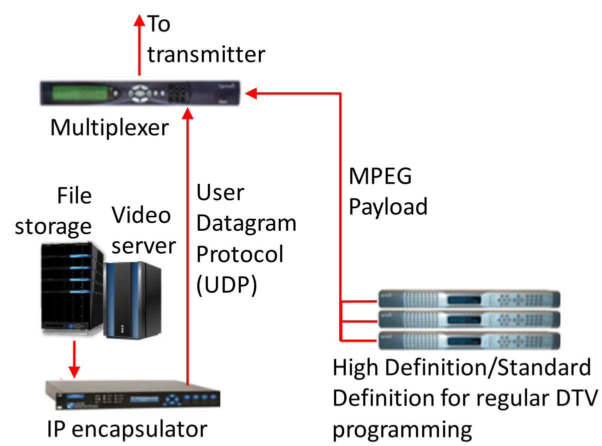

Figure 2. IP encapsulated MPEG multiplexed with station MPEG.

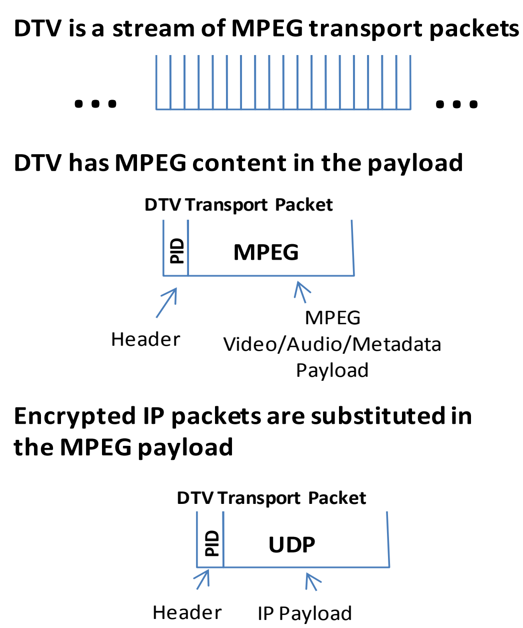

Figure 3. IP packet substitution in transport payload.

packets that contain IP data in the payload. Software installed at each receive location identifies the packets with the appropriate PID and then de-encapsulates the IP data and passes the IP stream on where the forward error correction (FEC) algorithm is applied and files are reconstituted and retained on local storage. IP video streams are handed off to the video player for presentation. The receive device operating system only sees a stream of packets arriving from what appears to be a network interface.

Public safety and emergency management users receive these transmissions on a small antenna with USB dongle receiver connected to their mobile data terminal, laptop, other mobile computing device, or even a Linux appliance developed by SpectraRep to provide WLAN or other access to the STDTVD signal as shown in Fig. 4. The receiver itself is a commercial off the shelf (COTS) device and sells for under $100. This low cost and DTV broadcast signal availability support use in emergency go kits where they can be handed out as needed, even to other agencies or volunteers.

C. Who Uses It?

1) Clark County, Nevada: The Clark County School District operates the nations longest running operational STDTVD system in Las Vegas, Nevada. For the last eight years, School District Police have employed STDTVD operationally to improve school security by delivering video, files, alerts and updates when needed during an emergency. School floor plans (pulled from the school district repository server each night), security video (up to 3,500 hundred cameras available), and other data is datacast to school security personnel responding to an incident at one for the 350+ schools in the Clark county school system. Bandwidth for these transmissions is provided by Vegas PBS [4], Southern Nevada Public Television, Inc. (SNPT). Nevada was awarded the IACP-iXP Excellence in Technology Award from the International Association of Chiefs of Police (IACP) for their school security technology application (see [5]).

2) Hampton Roads. The Virginia Tidewater Consortium for Higher Leraning (VTC) secured Urban Area Security Initiative (UASI) funding to build a system to improve security at several universities in the Hampton Roads area. Old Dominion, Regent, Hampton and Norfolk State universities use datacasting over WHRO-TV [6] to deliver incident response data. These data include building blueprints, lists of hazardous materials, emergency contact information and more. Receivers are currently installed in campus police cruisers, dispatch centers and other campus locations. SpectraRep is currently in the process of adding receivers at local police and fire locations so they will have more information when responding to an incident on campus. In addition to incident data, each school can send targeted alerts, warnings and updates to specific receivers allowing them to communicate with units in the field, even when the cell network is congested.

3) District of Columbia July 4th celebration. The United States Park Police (USPP) use datacasting to deliver

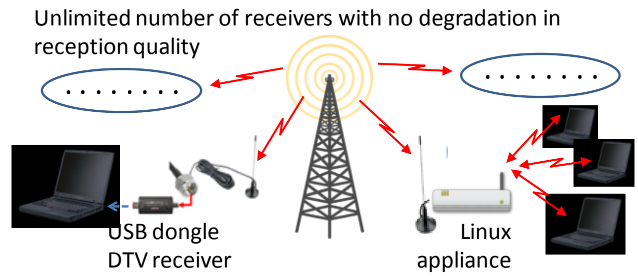

Figure 4. STDTVD receiver options: USB dongle or Linux appliance with WiFi re-distribution.

surveillance and helicopter video to multiple agencies in the National Capitol Region (NCR) during large crowd events. Like many law enforcement agencies, the USPP was forced to rely on cellular carriers to share data and video. Those systems can become compromised when the public consume most or all of the data transmission bandwidth as there is no Wireless Priority Service (WPS) for data. The USPP has been using datacasting to bypass the cellular congestion issue and get helicopter and surveillance video, as well as weather information, incident response data and alerts to targeted recipients, both internal officers and external agencies (see [7]).

4) City of Baltimore Police Department. The Maryland Emergency Management Agency (MEMA) is located in an older building with limited bandwidth expansion options. During major events, the City of Baltimore's Police Department (PD) has cameras around the city and Inner Harbor that are of interest to MEMA. Datacasting over Maryland Public Television (MPT) has been used to allow MEMA to see video from Baltimore at their EOC located elsewhere in the state. Baltimore PD has also used datacasting over MPT to share information and video with other agenceis. MEMA is hoping to secure funding to broaden their use of datacasting to include their own content generated at the EOC that would be shared back to Baltimore PD, County Emergency Managers and other agencies throughout the state.

D. Why Use It?

While technology to enhance and improve communications continues to improve, bandwidth remains a rare commodity. Without the bandwidth to deliver voice, video and data, even the best technology will fail. Datacasting is a rare combination of proven technology to manage content and information flows that also comes with its own nationwide delivery network. This combination frees up resources on other networks and assures delivery by not relying on resilient infrastructure that can become congested by other users.

Television stations pay millions of dollars in operating costs to maintain their broadcast operations. They are willing to provide a portion of their spectrum in return for recurring bandwidth revenue, but they also see it as part of their commitment to the community they serve. Since the broadcast infrastructure is already paid for by their broadcast television model, STDVTD can be very cost effective to deploy.

Datacasting combines the advantages of IP networks, that is, routing, encryption and receiver targeting, with the following advantages of broadcasting:

- Wireless metropolitan-wide coverage using resilient infrastructure that is monitored and maintained by professional engineers
- Natively broadcast multicast – send once receive many – which allows for an unlimited number of users to receive without congestion.

In this regard, STDTVD can augment existing public safety communication systems by providing video and data delivery to an unlimited number of users, while maintaining security and controlled distribution. Video and large file delivery could be offloaded from public safety radio systems, including the envisioned FirstNet Long Term Evolution (LTE) network, allowing those systems to be more efficient and reliable for other content.

E. Capabilties and Constraints

STDTVD offers unique capabilities that guide the development and operational use of a nationwide – and even international – operational architecture. Its unique capabilities include:

- Nationwide broadband signal coverage of much of the U. S. and many international populations in place today with a portion of their transmissions consisting of null packets (see Fig. 5).
- Offload of bandwidth-intensive applications, such as video, from cellular and LTE networks to avoid their congestion
- Provision of full and consistent Quality of Service (QOS) to targeted receivers because of the true multicast, versus unicast, protocol
- True multicast operation, because multicast is not natively deployed on cellular or LMR systems
- Resilience of TV stations, including antenna tower survivability, 7×24 engineering staff, and both immediate and long-term backup power systems
- Broadband infrastructure, including satellite services, to push content to participating STDTVD stations
- End-to-end encryption provided by AES-256 for targeted subscribers, so DTV station personnel have no access to STDVTD content
- Web-based Human-System interface (HSI) to control source content and manage STDTVD push of incident/event (Internet or VPN) to a DTV station's STDTVD server (i.e., the SpectraRep IncidentOne application)
- Sustainment by different business models than emergency management and public safety radio systems, including public television supported by the public broadcasting service (PBS) and commercial (for-profit) station revenue sources.

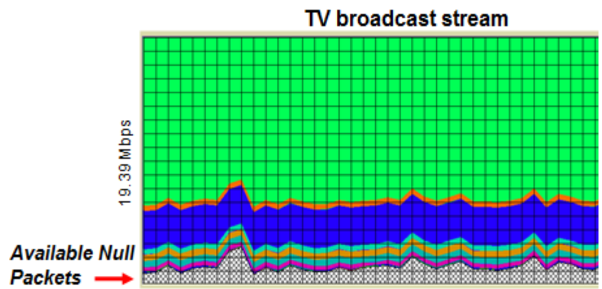

Figure 5. Single-station transport stream.

STDTVD is not natively a two-way communication system, that is, not over the DTV spectrum, but a return link can be implemented over other radio, wireless or Internet. In addition, two-way communications between DTV stations can be developed. In this case, each station would have receive antennas tuned to one or more adjacent station STDTVD transmissions, forming a mesh network. In addition, *carouselling* (i.e., repeated transmission), mobile DTV (i.e., added foreword error correction to improve reception while in motion), and path diversity, that is, two or more geographically spaced STDTVD stations multicasting the same content with scanning and cognitive DTV receivers, all mitigate the two-way issue.

STDTVD requires backbone connection to a DTV station to make content available for broadcast, but just such a resilient backbone is required for any critical telecommunications system; it is not unique to STDTVD.

Use of STDTVD requires content aggregation with prioritization maintained by a common authority, such as a state emergency management agency. Establishing STDTVD doctrine governance by these authorities providing guidance and control over what content is pushed at any moment is arguably the greatest challenge to nationwide STDTVD. History shows that such preplanned information sharing *to the detail* before the incident or event occurs is is necessary to prevent many unavoidable disasters becoming tragedies, that is, they were avoidable or their impact minimized or reduced.

F. What is Nationwide Architecture

SAIC with SpectraRep, LLC, and PBS seek to leverage the existing public television infrastructure to support public safety. PBS operates a satellite delivery network utilizing three transponders on multiple satellites to deliver programming to member stations. This same backhaul network can also be used to deliver public safety and emergency management data securely and selectively to any station in the country, which can then deliver STDTVD to selected end users in a given area or areas. For example, the Federal Emergency Management Agency (FEMA) could push hurricane response data from to a TV station in New Orleans, which would then pass it through to First Responders, National Guard, police and fire departments, hospitals and shelters, mobile and transportable command centers, essentially any group of individuals or even a single individual (e.g., a principle authority, such as a mayor or governor) over one of the most resilient wireless infrastructures the U. S. today.

Multiple stations can be aggregated to create regional networks that might encompass multiple cities, entire states, multiple states or even the entire country. Multiple users could send data concurrently, while blocking receipt by unauthorized recipients, while information-sharing interoperability can be improved by opening reception across agencies when needed.

Although SAIC and SpectraRep work with local, regional and state authorities, nationwide architecture would avoid holistic interoperability issues [3] in STDTVD deployment. These issues could arise because many local and regional jurisdictions within a single state receive DTV coverage from stations not in their state. In fact, public television stations in 16 states are "owned" and operated by state government authorities. Achieving holistic STDTVD interoperability in most states therefore requires a common multistate (nationwide) concept of operations (CONOPS) governing content aggregation doctrine, policy and procedures to be adopted by all state STDTVD authorities. In this way, STDTVD authorities in adjacent states can utilize the best possible broadcast stations to maximize the probability of content delivery to the required pushgroups.

II. National TV Infrastructure

A. Public Television

Approximately 20% of the broadcast television licenses in the United States are assigned to Non-Commercial Educational (NCE) licensees, encompassing 396 full power and more than 600 low-power translator stations. These stations are commonly referred to as "Public Television." The Public Broadcasting Service (PBS) is a membership organization that provides a national infrastructure for distribution to, and interconnection of, Public Television stations across the country. Not all public television stations are members of the PBS system.

PBS maintains a robust content delivery and distribution network that includes satellite, microwave, fiber and copper connectivity elements to participating stations. Television programs can be uplinked from multiple locations, terrestrial networks, including state and regional systems, provide primary and redundant paths to all PBS member stations. This same infrastructure could also be used to distribute public safety data, emergency information, consumer alerts, etc. to any PBS station in the country for terrestrial redistribution. It would also be possible to receive this private data directly from the satellite broadcast if desired.

1) Infrastructure: The PBS national distribution architecture shown in Fig. 6 provides greater than 99.95% availability of service delivery to the entire Public Television System. Ku- and C-band Satellite distribution is based on the widely adopted DVB/S2 [8] and H.264 [9] standards.

2) Station connectivity: PBS member stations all receive 12 linear television streams, including five high-definition and seven standard-definition feeds, each of which can be configured to carry secure datacast content from a single national ingest point to all stations. Each station can then be configured to broadcast datacast content in their local coverage areas via over-the-air DTV datacasting. Stations also have the option to ingest local datacast content in addition to regional or national content.

3) Business model: By license, public television stations are local, mission-based not-for-profit entities that serve their local communities and citizens. STDTVD services align well with station missions.

4) Coverage and population reach: PBS member stations collectively provide the largest coverage of the U.S, population of any single entity, and with multiple overlapping stations in many locations. Approximate coverage is shown in Fig. 7.

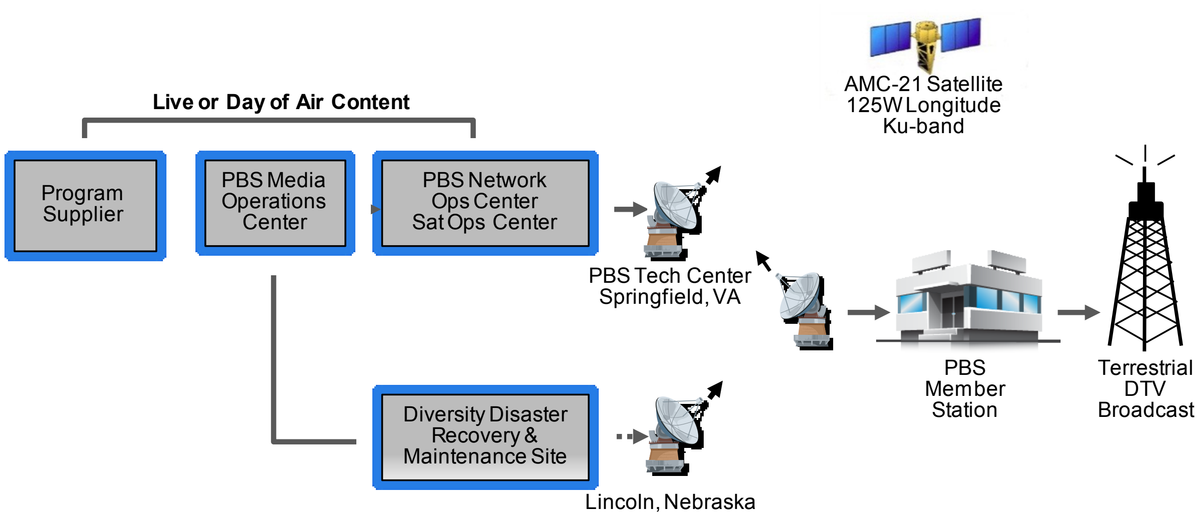

Figure 6. PBS National Distribution Architecture.

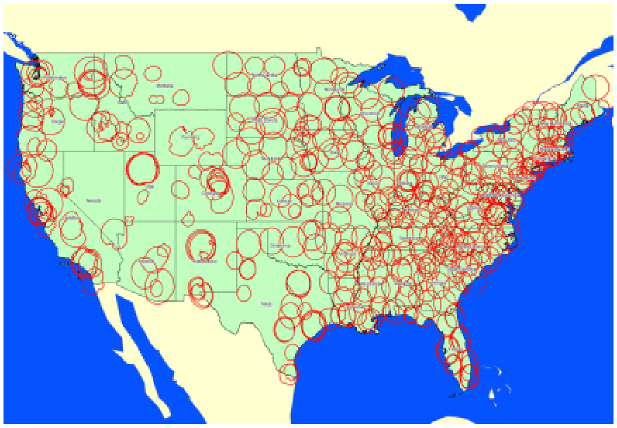

Figure 7. US coverage by the Public Broadcasting Service.

5) Resilience: The PBS national infrastructure is a high-availabilty, enterprise-class implementation with a large amount of redudancy, both in terms of equipment and physical diversity of operational sites. Satellite networks are well-known for their high-availability, and the PBS distribution system includes a number of satellite disaster recovery options based on both contractual restoration requirements and operating procedures. At the station level, a significant majority of stations have hardened infrastructure that includes more than 72 hours of backup power from their origination systems through their transmitters.

B. Commercial Television

1) Infrastructure: Commercial television infrastructure is similar to the Public Television infrastructure, duplicated on a smaller scale by each of the major commercial broadcast networks.

2) Business model: A condition of a commercial station's license is to act in the public interest, and support of emergency messaging has always been well-supported and adopted by commercial stations. Datacasting business opportunities are also feasible for commercial broadcast stations.

3) Coverage and population reach: Overall commercial television reach is consistent with the reach of public television stations, reaching approximately 98% of the U.S. population via over-the-air broadcast.

4) Resilience: As with public television stations, the majority of commercial stations have hardened power systems to allow stations to remain on the air during disasters.

C. DTV Datacasting for Emergency Alerting

The feasibility of using the nationwide distribution architecture and infrastructure provided by the datacasting capabilities of digital TV was recognized by the U.S. Congress when they included PBS and public television station infrastructure in the Warning, Alert & Response Network (WARN) Act of 2006 [10].

This act established the Commercial Mobile Alert System (CMAS) [11], a voluntary, national emergency alert system to enable an effective, reliable, integrated, flexible and comprehensive system to alert and warn the American people in situations of war, terrorist attack, natural disaster or other hazards to public safety and well-being. CMAS was recently renamed Wireless Emergency Alerts (WEA) [12].

As part of the Act, Public Television stations are required as a condition of their FCC license to carry emergency messaging datacasts provided by FEMA to PBS and distributed to stations using the PBS distribution infrastructure. The WARN Act included resources for stations to harden their transmission systems as well as the equipment to reliably carry, receive and integrate emergency messaging datacasts into the station's local broadcast channel. This system has been installed and is operational in all PBS member stations.

III. A National Architecture

A. Concept of Operations

Since "all incidents are local," and First and Supplementary Responders need immediate situational awareness to protect themselves as well as the public, the way in which STDTVD is used is critical to its acceptance and success. Providing direction of fire spread, location of armed perpetrators in a building or campus environment, traffic incident scenes, severe weather or HAZMAT plume forecasts, emergency management data, and other information quickly and securely over a wide area, is technically proven and available "today." The challenge – as it has been historically with any technology – is to configure its use to the greatest benefit.

Fig. 8 shows a notional hierarchical model for a CONOPS governing what is pushed and when. Of course, immediate safety-of-life incidents would likely gain top priority in a locality. Much like the school security application in Las Vegas, security cameras video of an armed robbery could be pushed by "panic" button activation to the local aggregation point for STDTVD distribution to nearby local and state police while the crime is in progress.

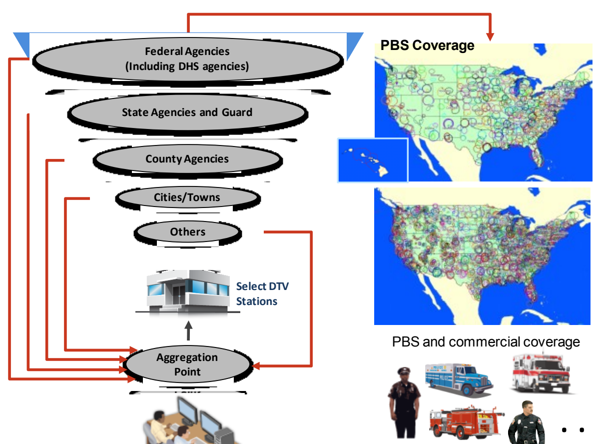

Figure 8. Nationwide STDTVD CONOPS and coverage.

B. Infrastructure

As observable from the Fig. 7 and Fig. 8 coverage contours, there are now over 1,782 full-power broadcast television stations in the United States. An additional 9,537 low-power stations augment full-power coverage by filling in coverage gaps. In addition to internally generated programming, most stations also receive content from networks, syndication, private suppliers and other sources. Typically, this content is delivered over satellite to one of many receive dishes already in place. That same existing backhaul can also be used to deliver STDTVD for terrestrial redistribution.

In addition to single-station delivery, multiple television stations can be joined together into fixed or ad-hoc networks of stations. Groupings could consist of two or more stations in a region, an existing statewide network or national network. In this way, a regional, state or national authority could target particular geographic areas as well as pushgroups to send the necessary information for the incident or event scenario at hand. One or more return paths using a variety of media could provide acknowledgement or content menu selection and request functions.

IV. Emerging Capabilities

Further advances in spectral efficiency, increased DTV transmission rates, and emergency communications for the public as well as receiver mobility options are emerging – all of these capabilities further enhance the STVTVD applications and utility.

A. Mobile Reception

Current television broadcasts in the United States can only be received while stationary. This is because the legacy 8 Vestigial Side Band (8-VSB) standard was designed for home reception using a rooftop antenna. Technology now exists, and is part of the Advanced Television Systems Committee (ATSC) broadcast standard See A/153 mobile DTV standard parts 1-10 [13].

Mobile reception requires additional transport layer FEC, so is less bandwidth efficient than legacy broadcasts. New receivers are required to receive mobile broadcasts, which are now available in certain cell phone and tablet models, as well as add-on dongles and USB adapters.

B. Mobile Emergency Alerting (M-EAS)

The current Emergency Alert System (EAS) utilizes broadcast and cable media to deliver alerts to the public. EAS began as CONELRAD in 1951 and continues to this day using Frequency Shift Keying (FSK) tones to deliver small amounts of data over analog radio signals to alert the public.

As cell phones became more pervasive, multiple efforts to reach those devices directly were explored. The Commercial Mobile Alerting System (CMAS) was created to warn the public on their smartphones, but CMAS is limited to 90 text characters. M-EAS is a new Advanced Television Systems Committee alerting standard that uses Mobile Digital Television broadcasts to deliver video, audio and data centric alerts during an emergency.

M-EAS [14] takes advantage of mobile Digital Television (ATSC DTV A/153) standard broadcasts to deliver multimedia alerts to the public on their cell phones and tablets. M-EAS extends public alerting to mobile devices allowing device wakeup, transmission of files and video. However, it requires a new generation of mobile device with mobile DTV receive capabilities. These devices are not widely available at this writing.

C. Advanced Television Systems Committee version 2.0 specification (ATSC 2.0)

The current ATSC digital television standard was adopted in 1996 and became broadly available in 1999. In order to assure compatibility with any television set, the standard locked in place MPEG transport, MPEG-2 as the video codec, and other core attributes. The standard has been updated several times, including the recent addition of support for mobile reception on cell phones and tablets. However, the core infrastructure has not changed.

ATSC 2.0 is a plan to take advantage of technical improvements to update the video codec (to H.264), add second-screen support, interactivity, file delivery and other enhancements. ATSC 2.0 is currently a candidate standard with adoption expected in 2014.

D. Advanced Television Systems Committee version 3.0 specification (ATSC 3.0)

With the ATSC version 3.0 specifications (ATSC 3.0), there will be an apparent balance between continually advancing technology and the need for fixed standards that assure interoperability with consumer products. Where ATSC 2.0 focuses on changes that will improve digital television, while maintaining backwards compatibility, 3.0 is a "clean slate." The ATSC is currently soliciting proposals for ways to improve the physical layer, add mobile reception as a native capability, improve bit density, add a return path, improve encoding efficiency, support Ultra (High Definition) HD (4k) resolution and other enhancements to improve broadcast television for the next several years. No definitive timeline has been established for 3.0, but it is conceivably 5-10 years away.

E. High Efficiency Video Coding (HEVC)

High Efficiency Video Coding (HEVC) is a new International Organization for Standardization (ISO) and International Telecommunications Union Telecommunications Standardization Sector (ITU-T) video compression standard. HEVC is also known as the ISO Moving Picture Experts Group (MPEG) and ITU-T Video Coding Experts Group (VCEG) H.265 encoding standard. The ATSC is expected to officially support a switch to HEVC in the next few years as part of their ATSC 2.0 initiative.

When the ATSC was creating the standard for digital television in the 1990's, MPEG-2 was the state-of-the art codec. Encoding technology has continued to improve since then, but the standard locked MPEG-2 in place. H.265/ HEVC, can produce video quality in one quarter of the bandwidth, compared to the current MPEG-2 standard. HEVC will be supported in mobile DTV broadcasts soon and is almost certain to replace MPEG-2 in ATSC 3.0, unless a better codec is developed before ATSC 3.0 is finalized.

F. Two-way communications

Although broadcast television provides a one-way true multicast broadband link, a two-way architecture can be realized by utilizing a separate transmission path for the return channel. An operational example of this architecture was utilized in the early cable modems deployment. Downstream Internet content was delivered over the high-speed cable, while the return (upstream) path was a standard telephone connection.

Successful tests have demonstrated that any existing return path can be bonded to the broadcast signal to create what appears to be a two-way system. Cellular Internet, the APCO/TIA Project 25 radio data channel, LTE, or any other existing voice or data communications path can be used to return data upstream to acknowledge receipt of content, request content, etc.

Another approach to two-way STDTVD has been envisioned as a broadband mesh network, in which in which receive antennas for multiple stations within radio line-of-sight range sit at the top of a DTV transmit tower. A two-way packet mesh network is then possible, spanning the country with resilient broadband infrastructure. Operations centers with resilient two-way communications (fiber, microwave, or both) would then be capable of wide-area broadband communications using this in-place network as wel. See Fig. 9.

STDTVD also helps solve a standard problem in many municipal areas, namely, police or other helicopter video is limited to the line-of-sight distance from the handheld receiver to the helicopter, and there is often no means of sharing that video live over a wide area. By placing the video receive antenna atop the DTV transmit antenna (e.g., 1,000 ft AGL), the LOS from the helicopter to the receiver is greatly increased as depicted in Fig. 9. Of course, now the helicopter video can be shared via STDTVD to as many recipients as desired.

G. First Responder Network Authority Integration

First Responder Network Authority (FirstNet) [15] brings much needed spectrum to public safety. The First Responder Network Authority will oversee the construction of a new nationwide public safety network for first responders on 20 MHz of spectrum in the D block. While this deployment will significantly enhance public safety communications and interoperability, there is concern that there is not enough spectrum, the construction timeline is too long and the $7 B allocated for construction will not be adequate.

Utilizing existing DTV spectrum to offload bandwidth intensive video and large files could mitigate those concerns. Broadcast television's native multicast transport is considerably more efficient than unicast architecture for delivering the same content to multiple recipients. Shifting that content off FirstNet LTE networks, enables FirstNet resources to support more unicast traffic, such as voice and interactive data, making it more efficient.

H. Cellular telephone receivers

As mentioned previously, recent additions to the ATSC digital television specification allow it to support reception on mobile devices, including smartphones. While this is currently achievable using external dongles and antennas, it is expected that this capability will become ubiquitous when it is included in the devices themselves.

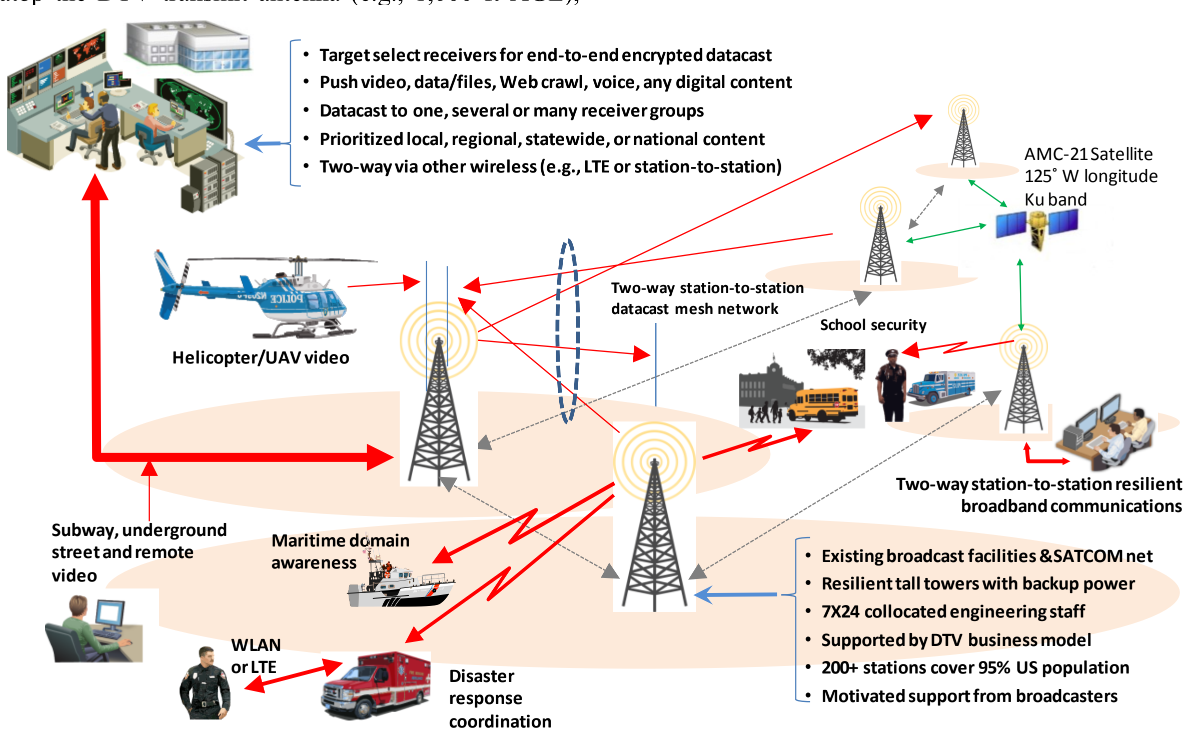

Figure 9. Potential resilient (two-way) meshed STDTVD network.

The inclusion of Mobile DTV (M-DTV) chipsets into smartphones will be driven by consumer demand and the desire for manufacturers to offer the latest technology. Once common, these same devices that allow consumers to watch live TV, will also allow that same broadcast signal to deliver secure encrypted targetable information to public safety.

If FirstNet incorporates M-DTV chips in the specification for FirstNet compatible phones, a second natively multicast path will exist that can deliver live video, files, updates and alerts over the television bandwidth, freeing up the limited FirstNet capacity for voice and unicast communications.

I. Achieving public safety availability and reliability

Researchers at SAIC, SpectraRep and WPI are preparing to evaluate several advanced methods for enhancing a national STDTVD architecture, including:

- Conducting extensive DTV spectrum measurements across multiple locations within a geographical region possessing similar signal propagation characteristics in order to better understand how signals propagating across these frequencies behavior in various terrains and signaling environments.
- Devising a computer model that combines these empirical spectrum measurements at different locations with known quantitative signaling characteristics for DTV transmission given specific terrains such that a broad range of DTV datacast networking scenarios can be explored.
- Discovering new transmit and receive diversity schemes that leverage multiple DTV broadcasting sites and multiple DTV receivers in order to further enhance the performance of the system in terms of error robustness.
- Creating new networking schemes based on the proposed DTV datacast architecture in terms of the routing of information from multiple sources to a target destination, as well as accurately modeling this network-level behavior.
- Implementing of a state-of-the-art research laboratory used to study and devise optimized DTV datacast algorithms for various terrestrial signal environments. It is expected that this proposed facility will be made available to the research community.

We will report on our progress in future publications.

V. GLOBAL OPPORTUNITIES

Television has converted, or is in the process of converting, to digital broadcasts throughout the world. Since the transport layer in every system is MPEG, the same process of substituting IP data in the MPEG transport packet (datacasting) would work anywhere in the world. Only the MPEG packet headers would have to be modified to conform to the local broadcast standard.

Many of the standards in other countries already support mobile reception, public alerting and other enhanced capabilities. As mentioned earlier, the U. S. is in the process of evaluating system enhancements to offer next generation capabilities, even at the expense of backwards compatibility. ATSC 2.0 and 3.0 are described earlier in this paper.

Datacast IP packets take on the attributes of the host system, meaning that mobile reception, partial carrier reception, multiple levels of transport layer error correction, etc., can be utilized if supported by the broadcast standard. As with all network topologies, and technology in general, enhancements to the transport layer result in improved service to the end user, regardless if the content is television programming or encrypted public safety data.

There are four primary digital television broadcast standards in use around the world as summarized in Table 1. North America and Korea use the ATSC standard. Europe, Africa and Australia use Digital Video Broadcasting-Terrestrial (DVB-T). Japan uses 1seg as described above, and China uses Digital Terrestrial Multimedia Broadcast (DTMB). Datacasting is supported in all of these broadcast standards as shown in Fig. 10.

TABLE 1. TELEVISION STANDARDS EMPLOYED INTERNATIONALLY.

Standard	Location	Transport	Modulation
ATSC	North America	MPEG	8-VSB
DVB-T	Europe	MPEG	OFDM[a] QPSK[b]/QAM
ISDB-T	Japan	MPEG	OFDM QPSK/QAM
DTMB	China	MPEG	OFDM QAM

a. OFDM – Orthogonal Frequency-Division Multiplexing
b. QPSK – Quadrature Phase Shift Keying
c. QAM – Quadrature Amplitude Modulation

VI. SUMMARY

The nations thousands of high-power resilient DTV transmission facilities and broadband capabilities offer an immediately available resilient broadband infrastructure covering 95% of the population of the U. S. Through the STDTVD capability, this infrastructure offers significant benefit to the law enforcement/security, public safety, emergency management, and other special disciplines. These stations have collectively invested many hundreds of millions of dollars and, sustained by a 75+ -year-old broadcast business model, provide an built-out broadband STDTVD resource in the U. S. and internationally. This resource provides a resilient, high-power mobile and mesh network capability for day-to-day use through major disaster communications. SAIC, SpectraRep, PBS and WPI researchers and engineers are working to realize the significant potential of this vastly underutilized infrastructure for public safety and emergency management communication needs.

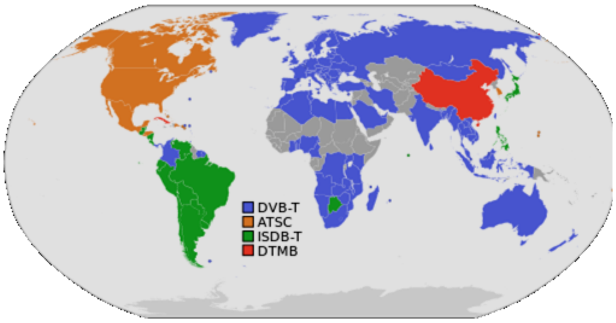

Figure 10. Television standards employed internationally [16].

The use of DTV broadcasts to provide encrypted transmission to selected pushgroups has been described, including a national architecture designed to service local needs on a moment-to-moment basis for short-lived responder needs, regional STDTVD for multijurisdictional incidents or events, and seamlessly to wide-area and even nationwide disaster and emergency response scenarios.

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