ENABLING NATO TELEMEDICINE INTEROPERABILITY WITH WEBRTC FOR STANAG COMPLIANCE

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Abstract: The WebRTC-based telemedicine framework represents a significant advancement in NATO's (North Atlantic Treaty Organization) pursuit of interoperability and effective healthcare delivery. Building upon STANAG 2517 (Standardization Agreement), the framework addresses challenges posed by incompatible systems and fragmented communication through a web-based, real-time collaboration platform. The aim of the interoperability tests was practical verification of the Polish WebRTC (Web Real-Time Communication) implementation according to NATO requirements, including data security. Demonstrated successfully at CWIX 24 (Coalition Warrior Interoperability Exercise), where eight NATO nations achieved interoperability, this solution ensures secure, scalable, and efficient medical support across multinational operations.

Keywords: interoperability solutions, military communication, multi-domain operations, secure communication protocols, STANAG 2517, telemedicine, WebRTC

INTRODUCTION

Novel technology can provide new possibilities to improve both patient care and survivability in civil and military operations. The battle experience from Ukraine shows a pressing operational need to make real progress in a realistic, prioritized development of basic capabilities supporting health care. In "NATO standard AJMedP-5 Allied Joint Doctrine for medical communications and information systems" [19], telemedicine is defined as 'the practice of medicine over a distance using information and communication technologies". The World Health Organization defines telemedicine as [24]: 'The delivery of health care services, where distance is a critical factor, by all health care professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment and prevention of disease and injuries, research and evaluation, and for the continuing education of healthcare providers, all in the interests of advancing the health of individuals and communities.' Telemedicine covers a variety of technologies enabling live two-way audio and video transmission between patients or paramedics and a medical expert at the distant site.

Telemedicine has become a vital tool in NATO's efforts to provide healthcare support across diverse and dispersed operational environments. With its ability to deliver medical expertise remotely via Information and Communication Technologies (ICT), telemedicine aligns with NATO's operational priorities. It is useful in all types of operations and gives value form the point of injury to the medical treatment facility (MTF) as well as between MTFs. Its strategic importance is rooted in its capacity to extend healthcare capabilities, reduce logistical burdens, and ensure continuity of care across multinational missions.

Building on the framework established in STANAG 2517 "Development and Implementation of Teleconsultation Systems" (refined in its 2018 version) [19], NATO has standardized telemedicine practices to enhance interoperability. Despite NATO's long-standing commitment to interoperability, achieving a telemedicine framework across member nations has been a persistent challenge. National systems often lacked compatibility due to differing technological standards, security protocols, and operational frameworks. Language barriers and varying levels of adoption further compounded these issues [11].

Previous approaches, including earlier versions of STANAG 2517 and multinational experiments, revealed the limitations of legacy systems. These efforts frequently fell short in enabling real-time collaboration due to incompatible data formats and insufficient infrastructure. The result was a fragmented telemedicine landscape that hindered NATO's ability to fully leverage the potential of ICT in healthcare delivery.

The adoption of web-solutions, particularly Web Real-Time Communication (WebRTC) [23], marks a shift in NATO's approach to telemedicine [12]. Unlike previous solutions, WebRTC enables real-time communication across national platforms through standardized protocols that ensure compatibility. This web-based approach allows nations to retain their sovereign telemedicine systems while providing the capability for cross-national communication when needed. Additionally, NATO can offer a shared platform as an alternative for joint missions.

Testing a WebRTC-based solution during the Coalition Warrior Interoperability Exercise (CWIX) 2024 provided compelling evidence of its effectiveness, demonstrating interoperability across eight NATO nations. This new paradigm not only overcomes the historical challenges of telemedicine but also establishes a foundation for future NATO operations. With the new version of STANAG 2517 [20], currently under ratification, defining WebRTC as the standard to be used, this technology exemplifies the potential for real-time, multinational collaboration in healthcare, fully aligned with NATO's evolving requirements. Some of the authors of this article are members of the COMEDS Health Information Systems and Technology Working Group (HIST-WG), actively contribute to the TeleHealth Panel, and have worked on the new version of the STANAG 2517 [20].

This article includes the subject of the research and answers questions about: what was studied, what was the purpose of the study, why the research problem was important, what was known so far, and how the research expanded knowledge about a given issue.

Rationale

NATO has long recognized the potential of telemedicine to enhance healthcare delivery in multinational operations, but achieving interoperability across member nations has proven to be a complex challenge. One of the primary obstacles has been the existence of divergent national systems. NATO nations historically developed their telemedicine platforms independently, resulting in a lack of compatibility

in communication protocols, data formats, and medical device integration. These differences created significant barriers to collaboration, particularly during joint missions where communication between nations is critical [6].

Another critical challenge has been ensuring the security of medical data in an environment where sensitive information must be protected. Variations in encryption standards, data-handling practices, and secure communication protocols across member nations further complicated efforts to establish a unified framework [18]. Without a consistent approach, these differences often resulted in fragmented telemedicine solutions that could not fully support NATO's operational objectives.

Related work

NATO's journey toward achieving interoperable telemedicine began a long time ago. The 2018 version of STANAG 2517 outlined the foundational framework for cross-national healthcare collaboration. While this earlier standard represented a significant step forward, the technologies it defined relied heavily on legacy communication protocols, such as H.323 [21] and Session Initiation Protocol (SIP) [17]. These protocols, though widely used at the time, were not inherently designed for the diverse and complex operational environments faced by NATO missions.

The H.323 protocol, widely used for voice, video, and data communication at the time, required extensive hardware setups and complex configurations. Its reliance on fixed network parameters and lack of flexibility made it difficult to adapt to rapidly changing military environments. SIP, while slightly more flexible, was similarly constrained by its need for static configurations and infrastructure, which were often incompatible across different national implementations. Furthermore, both protocols frequently required proprietary solutions, creating interoperability barriers between nations and leading to inefficiencies during joint operations [2].

One of the key challenges with these legacy systems was their complexity. Establishing a secure and functional connection often involves intricate configurations, such as manually defining network parameters and addressing firewall restrictions. This complexity slowed deployment, particularly in fast-moving military scenarios where rapid setup is essential. Additionally, the centralized architecture of these systems limited their scalability, making them less effective in large-scale operations or situations with high user demands.

Variability in national implementations further exacerbated interoperability issues, creating silos that hindered the exchange of information.

In contrast, the introduction of WebRTC in the updated STANAG 2517 marked a significant leap forward in NATO's telemedicine capabilities. WebRTC played a pivotal role in bridging the above-mentioned gaps between previously incompatible systems. Its open standard, available in all modern web browsers, allows real-time video, audio, and data communication [18]. WebRTC was designed specifically for real-time communication in dynamic environments, offering a browser-based solution that eliminates the need for dedicated, specific hardware or software installations [9]. Unlike its predecessors, WebRTC simplifies deployment through automated network configurations and reduces the reliance on centralized infrastructure while enabling nations to retain control over their sovereign systems [7].

WebRTC is supported by all major browsers such as Edge (Microsoft, USA), Firefox (Mozilla Foundation, USA), Chrome (Google LLC, USA), Safari (Apple, USA), Opera (Opera Software ASA, Norwegia), etc. WebRTC provides a flexible, open-source framework for real-time audio/video data exchange. WebRTC relies on a signaling server (for session negotiation), STUN/TURN servers (to traverse NAT/firewalls), and then one of several media-routing architectures:

1. Peer-to-peer (P2P): Once the signaling handshake is completed, two endpoints exchange media streams directly.
2. Mesh: In small multipoint calls, each participant opens P2P connections to every other participant, sending and receiving multiple streams.
3. Selective Forwarding Unit (SFU): A lightweight media server forwards each incoming stream to all other participants, minimizing client-side bandwidth and CPU without transcoding.
4. Multipoint Control Unit (MCU): A centralized server mixes all incoming media into a single composite stream, reducing client complexity at the cost of higher server load and potential latency.

With these options, WebRTC can be tailored for simple one-to-one calls or large-scale group conferences without requiring proprietary plugins or heavyweight infrastructure (Fig. 1).

In Table 1 a comparison of WebRTC with H.323 and SIP solutions is listed.

WebRTC is a better fit for military telemedicine because it delivers secure, low-latency communications over unpredictable, segmented
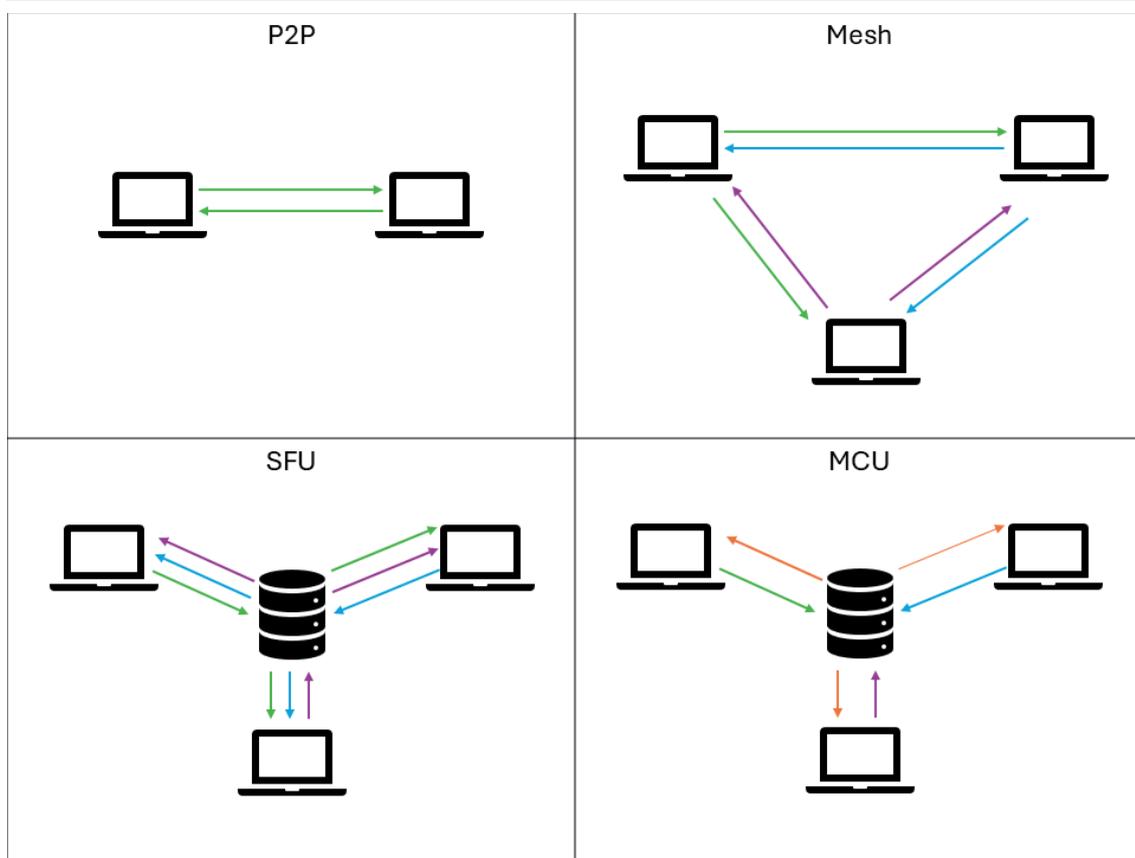
Fig. 1.   WebRTC architectures.

Tab. 1.   Comparison of telemedicine standards.

Characteristic	WebRTC	SIP	H.323
Primary use & model	Browser-native, peer-to-peer media & data; flexible signaling (app-defined).	Session control protocol for VoIP/Video; client–server; uses SDP for media negotiation.	Suite for multimedia conferencing; call control via H.225, media control via H.245.
Standardization	IETF (RTCWEB) + W3C (Web APIs).	IETF (RFC 3261 et al.).	ITU-T (H.32x series).
Media transport	SRTP for A/V (keyed by DTLS); Data-Channel via SCTP/DTLS.	RTP/SRTP for A/V.	RTP (optionally SRTP); legacy deployments often RTP clear unless H.235 used.
Security	Mandatory encryption (DTLS-SRTP); identity via certificates; browser isolation.	Signaling may be TLS; media SRTP optional; ZRTP/SRTP/Hop-by-hop TLS varies by deployment.	Encryption is optional via H.235 profiles; mixed in practice.
NAT traversal	Built-in ICE with STUN/TURN; aggressive consent freshness.	Typically uses ICE/STUN/TURN; requires SBCs/ALG tweaks in many networks.	H.460.18/.19 NAT traversal extensions; often needs SBCs/gateways.
Adaptive bitrate & congestion control	Built-in (e.g., Google Congestion Control, TWCC); per-sender simulcast/SVC via SFU.	Depends on implementation; typically, RTP/RTCP-based adaptation; less standardized end-to-end.	Vendor-specific; often MCU-centric control; less agile over the open internet.
Latency over the public internet	Very low (tens of ms to low hundreds) with UDP SRTP; tuned for real-time.	Low when engineered; can be higher with heavy SBC traversal.	Low on LAN; over the internet, often higher due to gateways/MCUs.
Browser & mobile support	Native in modern browsers; mobile SDKs available.	Not browser-native; requires softphone/SDK or WebSocket+gateway.	Not browser-native; dedicated endpoints/clients.
Call setup time	Fast (no registration needed; app-level signaling).	Registration and proxy routes can add setup overhead.	Often slower due to capability exchange (H.245) and MCU mediation.
Maturity & ecosystem	Modern, rapidly evolving; vast open-source/server options.	Very mature telephony ecosystem with carrier support.	Mature but declining outside room systems; strong vendor ecosystems.
Licensing/cost	Open standards; no codec fees for Opus/VP8; H.264 may involve patents.	Open standards; some codecs (e.g., H.265) licensed; platform costs vary.	Vendor solutions are often licensed; hardware endpoints are costly.
Typical deployment in telemedicine	Web/app-based consults, remote monitoring dashboards, embedded in EHR portals.	Call centers, contact routing, integration with PBX/help desks.	Conference rooms for MDT boards, legacy telepresence suites.

networks without adding software burden at the edge. Encryption is mandatory (DTLS-SRTP for audio/video and secured data channels), so sessions are "secure by default" rather than relying on careful configuration. Built-in NAT traversal via ICE with STUN/TURN lets clinicians and medics connect across bases, ships, and coalition networks that sit behind strict firewalls, while modern congestion control, packet-loss concealment, and adaptive bitrate keep streams usable over LTE, SATCOM, and tactical radio links. Being browser-native, WebRTC minimizes the footprint on hardened or managed devices, simplifying accreditation, patching, and rapid deployment to forward locations. It also supports flexible topologies, peer-to-peer for one-to-one consults and SFU/MCU media servers for care-team conferences, and the data channel allows secure exchange of telemetry, forms, and device readings alongside video without bolting on separate systems. In practice, this combination of secure-by-default design, resilience on contested links, minimal client overhead, and scalable architecture aligns tightly with operational and clinical requirements in the military environment. In coalition operations, WebRTC flips the interoperability burden: instead of forcing every nation's bespoke telemedicine stack to interconnect with every other, it provides a neutral, standards-based layer that runs in any modern browser. Because participants can join with the equipment they already have—laptops, tablets, or hardened endpoints with a compliant browser—coalitions gain an immediate common operating picture without custom client installs or fragile, bilateral gateway projects. This shortens time-to-operate and de-risks multinational deployments while still allowing controlled bridges to nation-specific systems where needed.

METHODS AND RESULTS

The proposed WebRTC-based framework for NATO telemedicine aims to balance interoperability and operational efficiency. Each NATO nation maintains its existing telemedicine platforms, preserving sovereignty over its systems while adhering to interoperability standards defined in STANAG 2517. These national platforms are complemented by the deployment and usage of WebRTC-based solutions, enabling real-time communication without the need for additional software or complex configurations. When inter-nation communication is required, one nation's platform can be accessed and utilized by others through WebRTC capabilities, as it is web-based and operates on any device. This approach removes the need for centralized, uniform infrastructure and simplifies implementation.

WebRTC's adaptability relies on advanced technologies, including the VP9 codec [22], Scalable Video Coding (SVC), Selective Forwarding Unit (SFU) architecture [8], and the integration of Interactive Connectivity Establishment (ICE) Lite [10] framework. Together, these technologies enable efficient, high-quality communication, ensuring the framework's robustness in diverse operational scenarios.

The VP9 codec [22], developed by Google (Google LLC, USA), is a highly efficient video compression technology optimized for real-time communication. It delivers superior video quality at reduced bandwidth compared to its predecessors, VP8 and H.264 [3], making it ideal for telemedicine applications where clarity and reliability are crucial. VP9 dynamically adjusts bitrates to accommodate fluctuating network conditions, ensuring a stable and high-quality video stream even in bandwidth-constrained environments. This capability is particularly important in NATO operations, where connectivity can vary significantly between locations and participants, especially on the tactical level, and with possible jamming.

The integration of SVC [16] within VP9 enhances adaptability by encoding video streams into multiple layers. Each layer corresponds to a specific quality or resolution, allowing clients to receive the highest possible quality based on their current bandwidth and processing capabilities. For example, a client with robust network connectivity can access a full high-definition stream, while one on a lower-bandwidth connection can receive a lower-resolution version, reducing the strain on network resources. This dynamic scalability ensures a consistent user experience across all participants and supports NATO's goal of achieving interoperability in telemedicine.

Selective Forwarding Unit (SFU) architecture (Fig. 1) optimizes media distribution by relaying streams between participants without mixing or altering them. Unlike Multipoint Control Units (MCUs), which process and mix streams at the server level, SFUs selectively forward original streams to participants, preserving quality while reducing server load and latency. This approach enhances scalability, as an SFU can handle large numbers of connections with minimal computational overhead [1].

In NATO telemedicine, the SFU plays a critical role by managing multiple streams from diverse
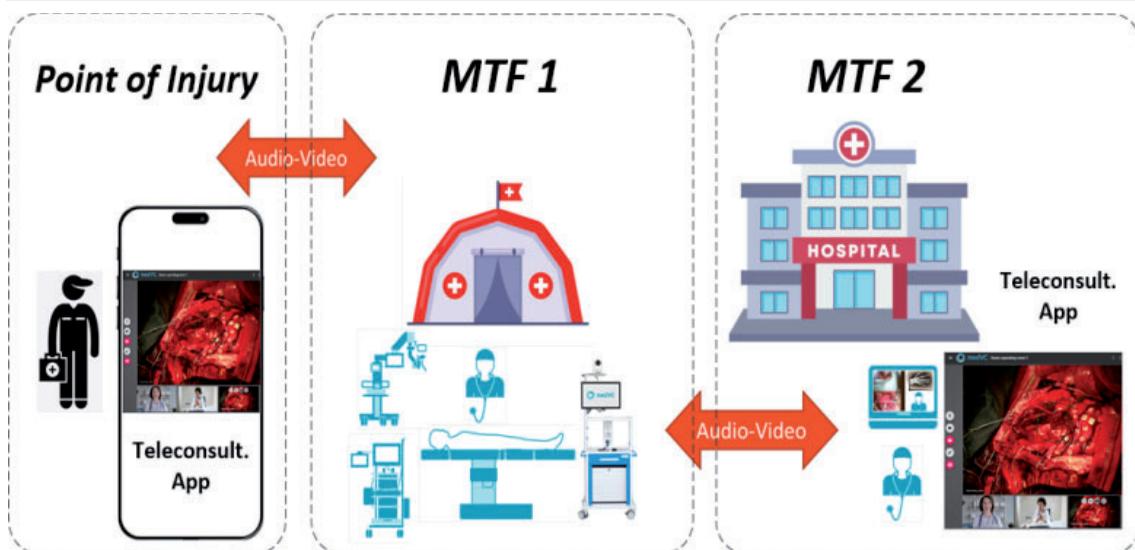
Fig. 2.   Test scenario for telemedicine system. MTF 1 - Medical Treatment Facility Role 1.

sources, such as medical specialists and field personnel. It ensures that participants only receive the streams they need, tailored to their network and device capabilities. The incorporation of SVC further enhances this by allowing the SFU to forward specific layers of a stream based on the participant's conditions. Additionally, the SFU is designed to be lightweight on resources, making it highly efficient and capable of functioning without a connection to the public internet, allowing it to operate in closed network environments. This is crucial for military operations, where secure and isolated communication systems are often required to maintain operational security and resilience in contested or remote areas where public internet access is unavailable or unreliable.

The SFU's integration of ICE Lite ensures connectivity across various network configurations, including environments with firewalls or NATs [10]. ICE Lite simplifies the negotiation process by using a single predefined public address for the server while delegating the responsibility of candidate discovery and testing to clients. This streamlined approach reduces server complexity and enhances scalability. For NATO telemedicine, ICE Lite enables the SFU to manage multiple simultaneous connections efficiently, maintaining reliable communication in challenging network conditions.

The framework adheres to NATO's stringent security and operational standards to ensure its reliability in military contexts. WebRTC incorporates end-to-end encryption using DTLS (Datagram Transport Layer Security) [15] and SRTP (Secure Real-Time Transport Protocol) [5] to protect all communications. This ensures compliance with NATO's data protection and confidentiality requirements, making the solution suitable for handling sensitive medical information in multinational operations.

Practical implementation of WebRTC-based framework was developed as part of the Polish MEDICS (Medical Information Management and Evacuation Support System on the Battlefield) project, supported by the National Center for Research and Development (SZAFIR program, grant no. DOB-SZAFIR/09/A/039/01/2020). One of the project's primary goals was to develop an advanced telemedicine system capable of supporting NATO's medical multinational operations. It was led by the Military Communications Institute and included partners such as the Poznań Supercomputing and Networking Center (PSNC), medVC.eu sp. z o.o., and the Military Institute of Aviation Medicine (WIML).

The system is designed with minimal client and server requirements, reducing deployment complexity and cost. On the client side, only a modern web browser is needed to access the telemedicine services. For servers, the use of SFUs ensures efficient management of media streams without requiring resource-intensive processing. SFUs forward streams selectively to clients based on their preferences and capabilities, reducing latency and maintaining high performance even with many participants [8].

The NATO Standardization Agreement (STANAG) 2517 has been instrumental in guiding the development of interoperable telemedicine systems across NATO nations. Refined in subsequent iterations, it provides a comprehensive framework for the deployment of telemedicine in multinational operations. The document defines high-level functional requirements such as real-time audio and video
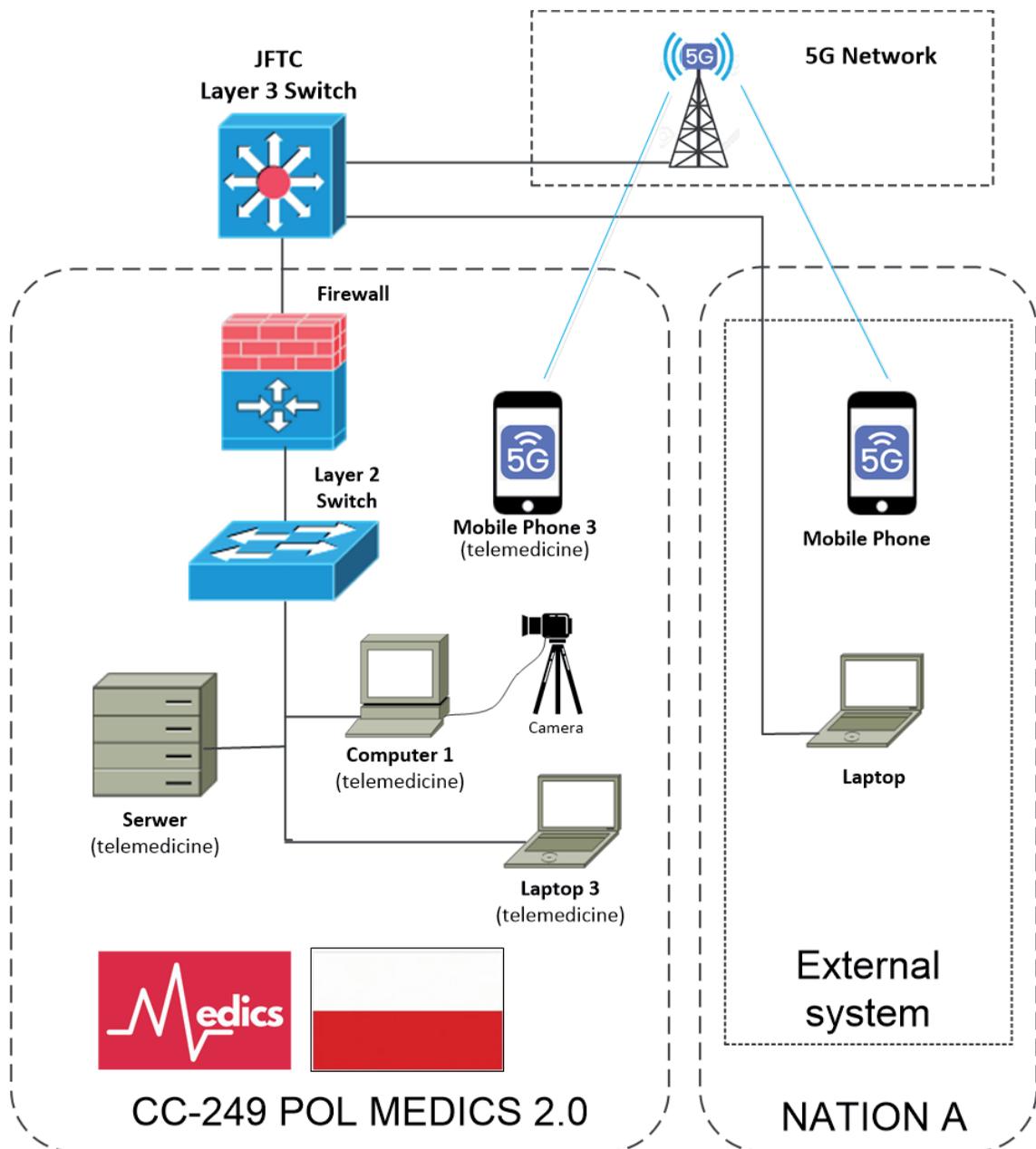
Fig. 3.   Architecture of the MEDICS setup at CWIX 24.

communication, integration with medical devices, and secure data transmission, ensuring alignment with NATO's operational needs. STANAG 2517 also serves as a blueprint for achieving interoperability by standardizing communication protocols and data formats. By setting these standards, the agreement ensures that telemedicine systems developed by individual nations can interact with one another. This approach addresses the historical challenges of incompatibility and fragmentation, enabling NATO to adopt a unified strategy for healthcare delivery in both Article 5 and non-Article 5 missions.

The Coalition Warrior Interoperability Exercise (CWIX) 2024 provided a practical demonstration of how WebRTC-based telemedicine system can solve interoperability issues. The common test scenario assumed the information exchange between the Point of Injury and MTF Role 1 as well as between MTFs (Fig. 2) and other posts. Different nations played the role of the medical staff on the Point of Injury and MTFs and tested interoperability of their national and NATO systems.

In this exercise, Poland provided a WebRTC-based telemedicine solution and hosted the central server (Fig. 3) that enabled NATO nations (marked as "Nation A") to connect. The exercise
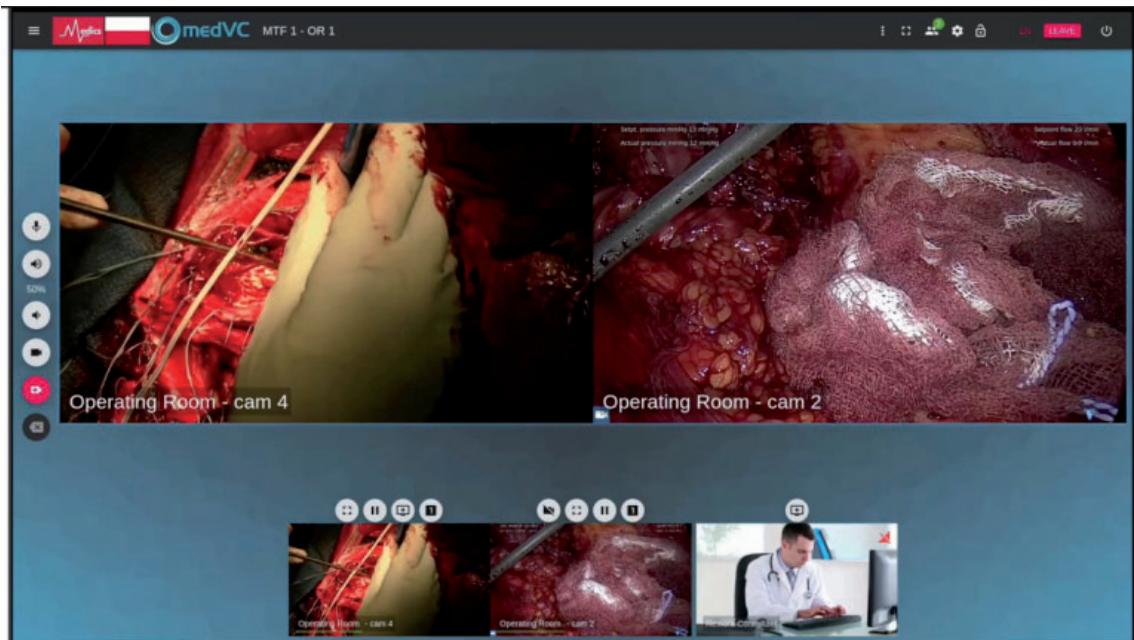
Fig. 4.   Polish WebRTC telemedicine application used at CWIX 24.

validated that telemedicine solutions could operate effectively across national boundaries, even when utilizing diverse hardware and software configurations.

A total of eight nations (The United Kingdom, the Netherlands, Germany, Finland, Spain, The United States, Hungary, Poland) tested the system, with the Polish team validating connections from different telemedicine terminals, laptops, and military-grade tablets, smartphones without requiring any installations, simply by accessing the system through their web browsers. Videos from cameras deployed in two operating rooms were transmitted and shared with participants on their national terminals (laptops, tablets, mobile phones) during the telemedicine session. The telemedicine server was responsible for gathering video from connected cameras (standalone and built-in) and distributing them among all telemedicine session participants.

The presented solution does not require a connection to the Internet, it was deployed in a separated unclassified network. graphical user interface (Fig. 4) enables each participant: selection of available videos, stopping the video, and drawing on the freeze-frame. All drawings on the freeze-frame were shared at the same time with the other telemedicine session members. The WebRTC platform was tested across various operating systems, including Windows, Linux, and Android, as well as multiple web browsers, including Chrome, Chromium, Edge, Firefox, and Safari. Connectivity between terminals was provided via wired LAN, Wi-Fi, and a mobile 5G network. The technology demonstrated resilience under varying network conditions, utilizing advanced video codecs like VP9 [22] with Scalable Video Coding (SVC) [16] to optimize performance despite bandwidth fluctuations. The inclusion of advanced features such as multilingual user interfaces, multiple video feeds, and telestration further enhanced the effectiveness of the telemedicine solutions, making them adaptable to the operational needs of multinational teams. Consistent with CWIX's mandate to validate cross-nation interoperability under exercise constraints, the 2024 campaign prioritized demonstrating that Nations could interoperate via a browser-based WebRTC edge on segregated coalition networks. Consequently, systematic performance benchmarking, e.g. end-to-end session setup time, ICE success rates, packet loss, and jitter, was intentionally out of scope for this event. Accordingly, the present work focuses on qualitative interoperability outcomes. Quantitative performance measurements must be undertaken in a controlled study under repeatable network conditions to generate aggregated metrics.

The MEDICS WebRTC-based implementation of a telemedicine framework offers significant operational advantages for Poland and NATO. The ability to provide immediate access to cross-border medical expertise during missions is one of its most impactful benefits.

In military scenarios, where quick decision-making can mean the difference between life and death, the framework facilitates real-time

consultations between field personnel and specialists located in different nations. This capability ensures that medical expertise is not confined to geographic boundaries, enabling soldiers and medical teams to receive the best possible guidance regardless of their location [11].

Another critical operational advantage is the reduction in time-to-treatment. Through the integration of synchronous video consultations and data sharing, medical teams can diagnose and treat patients more efficiently. The framework eliminates delays caused by traditional communication methods, such as email or asynchronous data exchange, ensuring that life-saving decisions can be made in real time [13]. This rapid response capability significantly enhances the survivability of injured personnel and supports NATO's overarching mission of preserving the well-being of its forces.

The framework's inherent scalability provides NATO with the flexibility to adapt to varying operational needs. Whether supporting small-scale humanitarian missions or large-scale military operations, the system can be scaled up or down based on demand. This adaptability ensures that NATO can respond effectively to a wide range of scenarios without requiring extensive modifications or additional infrastructure investments. By leveraging WebRTC's browser-based architecture, the framework can also be deployed rapidly in response to emerging crises, enhancing NATO's readiness and operational resilience.

The system's reliance on open standards ensures that it is accessible to all NATO members, regardless of their existing infrastructure. This inclusivity fosters a more cohesive alliance, allowing nations to work together more effectively in joint operations [14]. Additionally, the framework's user-friendly interface and multilingual support reduce training requirements, ensuring that personnel can quickly adopt the system and use it effectively in the field.

In breaking down traditional communication barriers, the WebRTC-based telemedicine framework exemplifies NATO's commitment to innovation and collaboration. It not only enhances the alliance's operational capabilities but also strengthens its ability to respond collectively to the complex challenges of modern military operations.

The implementation of the WebRTC-based telemedicine framework is designed to provide NATO with flexible deployment options that accommodate the diverse needs of its member nations. One of the key principles of this framework is that nations retain their existing telemedicine systems. This approach respects national sovereignty while ensuring compatibility through the usage of WebRTC-based solutions. By using WebRTC's open standards and browser-based architecture, nations can interconnect, enabling real-time collaboration during missions.

In scenarios requiring extensive multinational cooperation, NATO can provide a centralized WebRTC-based telemedicine system. This system serves as a primary option for nations without telemedicine infrastructure or as a fallback solution when rapid deployment is needed. The centralized system is designed to operate independently or alongside national platforms, offering a unified communication environment for joint operations. It ensures that all participants, regardless of their individual systems' capabilities, have access to secure and interoperable telemedicine services.

Effective user integration is critical to the success of the WebRTC-based telemedicine framework. To minimize training requirements and facilitate rapid adoption, the framework emphasizes intuitive user interfaces that are both accessible and easy to navigate. The design prioritizes simplicity, ensuring that personnel with varying levels of technical proficiency can operate the system effectively with minimal instruction.

To further streamline adoption, NATO can develop standardized training modules tailored to the specific needs of its member nations. These modules would focus on the core functionalities of the WebRTC system, such as initiating video consultations, sharing medical data, and utilizing advanced features like telestration (drawing on the video picture for highlighting areas) [4]. By providing consistent and comprehensive training materials, NATO can ensure that all personnel are equipped to use the system efficiently.

In addition to training, the establishment of standardized operating procedures (SOPs) is essential for consistent usage across multinational teams. These SOPs should outline best practices for initiating and managing telemedicine sessions, handling sensitive medical data, and coordinating between national systems and NATO's centralized platform. By adhering to these procedures, users can ensure communication and avoid potential interoperability issues during missions.

DISCUSSION

The implementation of a WebRTC-based telemedicine framework marks a significant advancement in NATO's pursuit of interoperability and enhanced healthcare delivery across multinational operations. Building upon the

foundational standards established in STANAG 2517, this framework addresses historical challenges, such as incompatible systems, security concerns, and fragmented communication channels, by leveraging modern technologies and an open, web-based architecture.

Under STANAG 2517, telemedicine capabilities must use standardized communication protocols and datasets within a common reference architecture; protect personal medical data through encryption while maintaining confidentiality, integrity, and availability; operate effectively under variable or low bandwidth; and be deployable as web applications that other nations can access with only a browser. WebRTC directly implements these requirements and is explicitly cited by STANAG 2517 as a technology to be used, as it provides real-time audio, video, and data with encryption by default (DTLS-SRTP), satisfying the security prerequisites. Its built-in NAT/firewall traversal and adaptive media behavior sustain service when bandwidth is constrained, aligning with the standard's expectation for low-bandwidth operations. Because WebRTC is browser-native, it enables the STANAG-envisioned model in which nations can join from their existing devices without installing bespoke clients; interfaces can be localized so each user sees the user interface in their own language

The interoperability tested during CWIX 24 enabled practical verification of Polish WebRTC implementation, where MEDICS team representatives provided eight NATO nations with a telemedicine service enabling real-time collaboration and efficient medical support within the multinational scenario. The Polish MEDICS project played a pivotal role in providing the central server and validating the system's operational capabilities, further solidifying the framework's practicality in diverse operational contexts.

Operationally, the framework enables immediate access to cross-border medical expertise and reduces time-to-treatment, significantly enhancing NATO's ability to respond to medical emergencies. Strategically, it delivers cost efficiencies through resource sharing and system compatibility, ensuring scalability and adaptability to a wide range of mission requirements.

The WebRTC-based telemedicine framework provides a foundation for NATO's healthcare operations, but its potential extends far beyond its current scope. By integrating emerging technologies such as artificial intelligence (AI), the framework can evolve into a comprehensive tool for enhanced medical diagnostics. AI-powered features, such as automated image analysis and predictive health

modelling, could assist medical professionals by providing rapid, accurate assessments of patient conditions. This integration would not only improve the quality of care but also reduce the workload for medical teams in high-pressure environments.

Another promising avenue is the potential for remote robotic surgeries enabled by WebRTC. Advances in latency optimization and high-resolution video transmission make it feasible to perform complex surgical procedures from a distance. In scenarios where deploying specialized surgeons to the field is impractical, this capability could prove life-saving. The ability to control robotic surgical instruments remotely, combined with real-time audiovisual feedback, could redefine battlefield healthcare.

Beyond telemedicine, WebRTC has demonstrated the viability of using web-based technologies for other military applications. By replacing traditionally heavy, resource-intensive applications with lightweight, accessible web-based solutions, NATO can unlock opportunities across various domains. These include command and control, training simulations, and logistics management. For instance, web-based platforms could enable real-time multilingual collaboration among logistics teams or provide secure, high-definition video feeds for mission planning and execution. Adopting such technologies across operational areas would enhance NATO's effectiveness, streamline deployment processes, and foster deeper interoperability among its member nations.

However, achieving the full potential of this framework requires continued investment in training, standardized procedures, and iterative improvements. Regular participation in NATO exercises will be critical for identifying and addressing areas for enhancement, ensuring that the framework evolves alongside the alliance's operational needs.

CONCLUSION

In conclusion, the WebRTC-based telemedicine framework represents a paradigm shift in NATO's approach to healthcare and collaboration. By addressing traditional barriers and embracing modern innovations, it exemplifies the alliance's commitment to readiness and operational excellence. With its demonstrated success and expansive potential, this framework is poised to become a cornerstone of NATO's strategic capabilities in an increasingly interconnected world.

AUTHORS' DECLARATION

Study Design: Piotr Pawałowski, Maria Józefowicz, Marek Małowidzki, Rafał Piotrowski. **Data Collection:** Piotr Pawałowski, Maria Józefowicz, Marek Małowidzki, Rafał Piotrowski. **Manuscript Preparation:** Piotr Pawałowski, Maria Józefowicz, Marek Małowidzki, Rafał Piotrowski. The Authors declare that there is no conflict of interest.

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