A Comprehensive Taxonomy for Video Streaming in Smartphone Ad Hoc Networks (SPAN) within the Internet of Things (IoT)

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Abstract:-This comprehensive taxonomy provides a systematic framework for understanding and organizing the multifaceted aspects of video streaming within Smartphone Ad Hoc Networks (SPAN) operating within the Internet of Things (IoT) ecosystem. This taxonomy encompasses network architectures, communication technologies, routing protocols, video streaming protocols, quality of service considerations, security measures, scalability strategies, energy-efficient solutions, content delivery mechanisms, application scenarios, middleware, data analytics, user experience factors, and regulatory compliance, offering a holistic perspective for researchers, developers, and practitioners seeking to design, deploy, and optimize video streaming solutions in the dynamic and diverse context of IoT-enabled SPANs.

Keywords:- *Video Streaming, Smartphone, Ad Hoc Networks, Internet of Things.*

I. INTRODUCTION

In recent years, the proliferation of smartphones and the ubiquitous presence of Internet of Things (IoT) [23] devices have fundamentally transformed the way we consume and interact with multimedia content. One of the most prominent use cases in this rapidly evolving landscape is video streaming within Smartphone Ad Hoc Networks (SPAN) [1] operating within the IoT paradigm. As smartphones continue to serve as our digital companions, seamlessly integrating with an expanding array of IoT devices, the demand for efficient and reliable video streaming in SPANs has surged. This introduction sets the stage for a comprehensive exploration of the intricate ecosystem surrounding video streaming in IoT-SPANs, emphasizing the need for a structured taxonomy to navigate this complex terrain.

The IoT-SPAN ecosystem represents a convergence of technologies, where IoT devices collaborate with smartphones to create ad hoc networks for data exchange. These networks are highly dynamic and often characterized by limited infrastructure support, making them both challenging and promising for video streaming applications. IoT-SPANs are instrumental in various domains, including smart cities, healthcare, surveillance, and industrial automation, where real-time video content delivery and interaction with IoT devices are critical for efficient operation and decision-making.

Video streaming [21], [20] in IoT-SPANs presents a unique set of challenges and opportunities. Challenges encompass factors such as limited bandwidth, variable network conditions, energy constraints, security concerns, and the need for adaptive streaming to varying device capabilities. Simultaneously, opportunities lie in harnessing edge computing capabilities, efficient content delivery mechanisms, and the potential for data analytics and machine learning to enhance the video streaming experience. To address these complexities, it is imperative to establish a taxonomy that systematically categorizes and organizes the multifaceted components and considerations involved.

This paper introduces a comprehensive taxonomy designed to guide researchers, developers, and practitioners working within the IoT-SPAN video streaming domain. This taxonomy encompasses various dimensions, including network architecture, communication technologies, routing protocols, video streaming protocols, quality of service management, security measures, scalability strategies, energy-efficient solutions, content delivery mechanisms, application scenarios, middleware and analytics, user experience factors, and regulatory compliance. By providing a structured framework, this taxonomy aims to facilitate a deeper understanding of the domain, promote effective communication, and expedite the development and optimization of video streaming solutions tailored to the unique challenges and opportunities of IoT-SPANs. This paper consists of four sections. The IoT-SPAN Video streaming classification framework is discussed in Section II. In Section III a discussion is given and finally, the conclusion is given in Section IV.

II. TAXONOMY

The taxonomy for video streaming in smartphone ad hoc networks over IoT details are as follows:

A. Network Architecture:

- *Infrastructure-Based [10]:*

In infrastructure-based network architectures, IoT-SPANs leverage existing infrastructure components such as cellular networks or Wi-Fi access points for video streaming. These established networks offer a structured and organized communication framework.

Devices within the IoT-SPAN connect to centralized access points or base stations, which manage network traffic and provide connectivity. Smartphones and IoT devices communicate through these access points.

The existing infrastructure offers advantages such as reliable connectivity, predictable performance, and broader coverage areas. However, it may be subject to congestion and scalability limitations.

➢ *Infrastructure-Less (Mobile Ad Hoc Networks - MANETs) [15]:*

In infrastructure-less network architectures, IoT-SPANs are formed dynamically and on-the-fly, without relying on pre-existing infrastructure components. Devices within proximity establish direct peer-to-peer connections for data exchange.

MANETs are highly dynamic and flexible, making them suitable for scenarios where traditional infrastructure is unavailable or impractical, such as remote areas or disaster-stricken locations.

IoT devices and smartphones communicate directly with each other or through intermediate devices, forming ad hoc networks as needed.

- *Explanation:*

Network architecture is a fundamental consideration in IoT-SPAN video streaming. It dictates how devices within the network connect and communicate. The choice between infrastructure-based and infrastructure-less architectures significantly impacts the design and performance of video streaming solutions:

- *Efficiency:*

Infrastructure-based networks offer centralized control, making it easier to manage resources and optimize video streaming. Infrastructure-less networks are more flexible but may require more robust routing and coordination mechanisms.

- *Coverage:*

Infrastructure-based networks benefit from broader coverage areas, especially in urban and suburban environments. Infrastructure-less networks are adaptable and suitable for scenarios with limited or no existing infrastructure.

- *Scalability:*

Infrastructure-based networks may face scalability challenges due to network congestion and capacity limitations. Infrastructure-less networks can dynamically scale by adding more devices to the ad hoc network.

- *Deployment Context:*

The choice between these architectures depends on the specific deployment context, ranging from urban environments with established infrastructure to remote locations where devices need to self-organize for communication. Understanding these architectural options is crucial for optimizing video streaming efficiency within IoT-SPANs.

B. IoT Devices:

➢ *Smartphones [3]:*

Smartphones serve as central devices within the IoT-SPAN ecosystem. They play a pivotal role in video streaming and network coordination.

Smartphones typically act as both video streaming clients (receiving and displaying video content) and, in some cases, video streaming servers (providing content to other devices).

They are equipped with processing power, high-resolution displays, and network connectivity, making them ideal for video playback and user interaction.

Smartphones also facilitate network coordination, managing connections between IoT devices, and controlling video streaming parameters.

➢ *IoT Sensors and Devices [5]:*

IoT sensors and devices serve as peripheral components within the IoT-SPAN ecosystem. They are specialized devices designed for specific data collection tasks in IoT applications.

These devices can include a wide range of sensors, such as temperature sensors, motion detectors, cameras, and environmental sensors.

IoT sensors and devices may interact with smartphones in several ways:

- *Data Collection:*

They collect data relevant to IoT applications and may transmit this data to smartphones for processing and analysis.

- *Data Presentation:*

Some IoT devices, such as cameras, provide video streams that smartphones can display for surveillance or monitoring purposes.

- *Control and Feedback:*

IoT devices may receive commands from smartphones for remote control or provide feedback to users through smartphone interfaces.

- *Explanation:*

IoT devices, including smartphones and specialized sensors, together form the foundation of the IoT-SPAN ecosystem. Their roles and interactions are essential for enabling video streaming and IoT data exchange:

- *Central Role of Smartphones:*

Smartphones act as hubs for video streaming, network management, and user interaction. They offer a rich user interface and processing capabilities for rendering video content.

- *Specialized Functions of IoT Devices:*

IoT sensors and devices are tailored for specific data collection tasks, and their data often contributes to the context of video streaming applications. Their interaction with smartphones enables a wide range of IoT-SPAN scenarios, including remote monitoring, environmental sensing, and control of IoT devices.

- *Collaborative Ecosystem:*

The collaboration between smartphones and IoT devices enhances the capabilities of IoT-SPANs. It enables seamless integration of video streaming with IoT applications and facilitates efficient data exchange between devices for real-time decision-making and user interaction.

C. Communication Technologies:

➢ *Wi-Fi [13]:*

Utilized for high-speed data transfer: Wi-Fi offers high data rates, making it well-suited for streaming high-quality video content within IoT-SPANs.

- *Ideal for Smartphone-Centric SPANs:*

In scenarios where smartphones play a central role in video streaming, Wi-Fi provides the necessary bandwidth and reliability for efficient data transfer.

- *Explanation:*

Wi-Fi is a preferred choice for scenarios where high-quality video streaming and data transfer are critical, such as in-home or office environments where Wi-Fi access points are readily available.

➢ *Bluetooth [27]:*

- *Used for Short-Range Connections:*

Bluetooth is a short-range wireless technology ideal for connecting devices within close proximity, making it suitable for local coordination and control.

- *Device Coordination:*

Bluetooth is often used for device coordination and interaction, including controlling IoT devices or connecting peripherals like headphones or speakers to smartphones.

- *Explanation:*

Bluetooth's low power consumption and short-range capabilities make it valuable for local device coordination and interactions, but it may not be suitable for long-distance video streaming.

➢ *Cellular Networks [14]:*

- *Employed in Scenarios with Cellular Coverage:*

Cellular networks provide extensive coverage and reliable connectivity in urban and remote areas, making them suitable for IoT-SPANs in various environments.

- *Extended Range and Reliability:*

Cellular networks can extend the range of IoT-SPANs, allowing devices to connect even when they are not in close proximity.

- *Explanation:*

Cellular networks are a robust choice for scenarios where IoT-SPANs need to operate across larger geographical areas, such as smart city applications or IoT deployments in remote locations.

➢ *Zigbee, LoRa, NB-IoT [12]:*

- *Utilized for Low-Power, Long-Range IoT Devices:*

Zigbee, LoRa (Long Range), and NB-IoT (Narrowband IoT) are wireless technologies optimized for IoT devices with low power consumption and long-range communication needs.

- *Suitable for Certain SPAN Configurations:*

These technologies are advantageous in scenarios where IoT devices must communicate over extended distances while conserving energy.

- *Explanation:*

Zigbee, LoRa, and NB-IoT are well-suited for specific IoT-SPAN configurations where long-range communication is essential, such as in agricultural monitoring, environmental sensing, or rural IoT applications.

- *Explanation:*

The choice of communication technologies is a critical consideration in IoT-SPAN video streaming. Each technology has distinct characteristics that influence network range, data rate, and energy consumption. Selecting the most appropriate technology or combination of technologies is essential for optimizing video streaming performance in IoT-SPANs:

- *Network Range:*

The range of communication technologies varies significantly. While Wi-Fi and cellular networks offer broad coverage, Bluetooth and short-range options are suitable for local device interactions. Choosing the right range is crucial for ensuring that video streaming devices can communicate effectively.

- *Data Rate:*

The data rate determines the quality of video streaming. High data rates, as provided by Wi-Fi and cellular networks, support high-definition video streaming. Low-power, long-range technologies may have lower data rates, affecting video quality and latency.

- *Energy Consumption:*

IoT devices in IoT-SPANs often run on limited battery power. Choosing energy-efficient communication technologies helps extend device battery life and ensures uninterrupted video streaming.

- *Application Context:*

The choice of communication technology should align with the specific IoT-SPAN scenario. Factors such as geographical location, device mobility, and coverage requirements influence the selection process.

D. Routing Protocols:

➢ *Proactive Routing (e.g., OLSR - Optimized Link State Routing) [9]:*

- *Precomputes Routes:*

Proactive routing protocols establish and maintain routes in advance, even before data needs to be sent. This proactive approach aims to reduce latency when data needs to be transmitted, as routes are readily available.

- *Reduces Latency and Packet Loss:*

By having precomputed routes, proactive routing minimizes the time it takes to find a suitable path for data, reducing delays and lowering the risk of packet loss.

- *Explanation:*

Proactive routing, exemplified by OLSR, is well-suited for scenarios where low-latency and reliable data delivery are crucial. It ensures that routes are always available, making it ideal for real-time applications such as video streaming.

➢ *Reactive Routing (e.g., AODV - Ad Hoc On-Demand Distance Vector) [4]:*

- *Establishes Routes on-Demand:*

Reactive routing protocols create routes only when needed. When a device wants to send data, it initiates a route discovery process, and the network establishes a path to the destination.

- *Reduces Overhead:*

Reactive routing reduces network overhead by not maintaining routes until necessary, which can be beneficial in scenarios with sporadic data transmission.

- *Potentially Increases Latency:*

The time required to discover and establish routes in reactive routing may introduce some latency, particularly for the first data packets sent to a new destination.

- *Explanation:*

Reactive routing, as exemplified by AODV, is suitable for scenarios where devices do not constantly communicate and routes do not need to be maintained at all times. It conserves network resources by creating routes on-demand.

- *Explanation:*

Routing protocols play a crucial role in determining how data flows within the IoT-SPAN network. The choice between proactive and reactive routing protocols impacts various aspects of network performance:

- *Latency:*

Proactive routing reduces latency by having precomputed routes available, making it preferable for real-time applications like video streaming. Reactive routing can introduce latency when routes are established on-demand.

- *Packet Loss:*

Proactive routing minimizes packet loss by ensuring reliable routes are available. Reactive routing may introduce some packet loss during route discovery.

- *Overhead:*

Reactive routing reduces network overhead by not continuously maintaining routes. Proactive routing consumes more bandwidth due to constant route updates.

- *Scalability:*

Reactive routing can be more scalable in large networks with infrequent communication, as it conserves network resources until needed. Proactive routing may be less scalable due to constant route maintenance.

The choice of routing protocol should align with the specific requirements and characteristics of the IoT-SPAN network, including data transmission patterns, latency tolerance, and resource constraints.

E. Video Streaming Protocols:

➢ *HTTP Live Streaming (HLS) [7]:*

Segments video into small files: HLS divides video content into smaller segments or chunks, typically in the form of .ts (Transport Stream) files.

- *Adaptive Streaming Based on Network Conditions:*

HLS adapts video quality in real-time by switching between different quality segments based on the viewer's network conditions, such as available bandwidth and device capabilities.

- *Explanation:*

HLS is widely used for delivering video content over HTTP and is especially suitable for adaptive streaming, ensuring a smooth and uninterrupted viewing experience under varying network conditions.

➢ *Dynamic Adaptive Streaming Over HTTP (DASH) [18]:*

- *Adapts Video Quality:*

DASH dynamically adjusts the video quality delivered to the viewer based on available network bandwidth [19] and the capabilities of the receiving device.

- *HTTP-Based:*

DASH utilizes standard HTTP protocols, making it compatible with web browsers and widely supported by streaming servers.

- *Explanation:*
  DASH provides a versatile solution for adaptive streaming, catering to a range of devices and network conditions [17]. It is suitable for delivering high-quality video over HTTP.

➢ *Real-Time Transport Protocol (RTP) [30]:*

- *Suitable for Real-Time Multimedia Data Streaming:*
  RTP is designed for real-time transmission of multimedia data, including video and audio.

- *Used with RTP Control Protocol (RTCP):*
  RTCP complements RTP by providing feedback and control information for efficient media synchronization.

- *Explanation:*
  RTP is essential for real-time video streaming applications, such as video conferencing and live broadcasting, where low-latency and synchronized delivery are critical.

➢ *WebRTC (Web Real-Time Communication) [8]:*

- *Enables real-time, browser-based video communication:*
  WebRTC is a framework that allows web browsers to establish peer-to-peer audio and video communication without requiring plugins or additional software.

- *Built-in Support for NAT Traversal:*
  WebRTC includes mechanisms for traversing firewalls and Network Address Translation (NAT) devices, making it suitable for direct communication between devices across the internet.

- *Explanation:*
  WebRTC is instrumental in browser-based video communication and live streaming applications, enabling seamless, real-time interactions directly from web browsers.

- *Explanation:*
  Video streaming protocols are fundamental in delivering video content to devices while adapting to network conditions and device capabilities:

- *Adaptive Streaming:*
  HLS and DASH provide adaptive streaming capabilities, adjusting video quality on-the-fly to match the viewer's network bandwidth and device capabilities. This ensures a smooth viewing experience even in varying network conditions.

- *Real-Time Communication:*
  RTP and WebRTC are designed for real-time communication scenarios, where low-latency, synchronized delivery, and interactivity are crucial. RTP is commonly used in applications like video conferencing, while WebRTC enables browser-based real-time video communication.

- *Compatibility:*
  The choice of video streaming protocol may depend on the compatibility requirements of the target devices and platforms. HTTP-based protocols like HLS and DASH are well-suited for web and mobile applications, while RTP and WebRTC cater to real-time communication use cases.

Selecting the appropriate video streaming protocol depends on the specific requirements of the IoT-SPAN video streaming application, including the target devices, network conditions, and desired user experience.

F. Quality of Service (QoS):

➢ *Bandwidth Management [31]:*

- *Allocates Available Bandwidth Efficiently:*
  QoS mechanisms manage and allocate the available network bandwidth among competing devices and applications to ensure fair and efficient use of resources.

- *Prioritization:*
  Bandwidth management may prioritize certain types of traffic or devices to ensure that critical applications, such as video streaming, receive the necessary bandwidth for smooth operation.

- *Explanation:*
  Bandwidth management is crucial in IoT-SPANs to prevent congestion and ensure that video streaming applications receive the necessary resources to maintain quality.

➢ *Quality Metrics [29]:*

- *Monitor Video Quality:*
  QoS monitoring involves the continuous assessment of video quality using metrics such as PSNR (Peak Signal-to-Noise Ratio) and SSIM (Structural Similarity Index).

- *Adaptive Streaming:*
  Quality metrics are used to determine when to adjust video quality levels based on network conditions and device capabilities, ensuring an optimal viewing experience.

- *Explanation:*
  Quality metrics play a pivotal role in adaptive video streaming, enabling real-time adjustments to video quality to match network conditions and provide viewers with the best possible experience.

➢ *Error Handling [2]:*

- *Manage Packet Loss:*
  QoS mechanisms implement error handling strategies to address packet loss, ensuring that lost packets are retransmitted or replaced to prevent interruptions in video streaming.

- *Network Disruptions:*

QoS also manages network disruptions by selecting backup routes or adapting to changing network conditions to maintain the video stream's continuity.

- *Explanation:*

Error handling is essential for ensuring uninterrupted video streaming by addressing common issues like packet loss and network disruptions that can affect the viewing experience.

- *Explanation:*

Quality of Service (QoS) management is critical for delivering a seamless and reliable video streaming experience within IoT-SPANs:

- *Bandwidth Allocation:*

Efficiently managing available bandwidth ensures that video streaming applications receive the necessary resources to maintain video quality and reduce latency. It prevents congestion and bottlenecks that could degrade the streaming experience.

- *Quality Monitoring:*

Quality metrics, such as PSNR and SSIM, continuously assess the video's quality. This data informs decisions about adjusting video quality levels in real time to provide the best possible viewing experience, even in fluctuating network conditions.

- *Error Resilience:*

Effective error handling mechanisms address issues like packet loss and network disruptions, preventing interruptions in video streaming. Error resilience ensures that viewers receive a continuous and reliable stream, even when network conditions are less than ideal.

Implementing robust QoS strategies within IoT-SPANs is essential for meeting user expectations and ensuring that video streaming applications can operate smoothly and adapt to changing network conditions.

G. Security:

➢ *Authentication and Authorization [26]:*

- *Ensures that Only Authorized Devices can Access and Stream Video Content:*

Authentication mechanisms verify the identity of devices or users attempting to access video streams, preventing unauthorized access.

- *Authorization:*

After authentication, authorization mechanisms define what actions or resources (in this case, video streams) the authenticated device or user is permitted to access.

- *Explanation:*

Authentication and authorization are fundamental for controlling access to video streams, ensuring that only trusted devices and users can view or interact with the content.

➢ *Encryption [26]:*

- *Secures Video Data in Transit:*

Encryption transforms video data into an unreadable format during transmission, making it inaccessible to unauthorized parties who may attempt eavesdropping.

- *End-to-End Encryption:*

Ensures that video content remains encrypted from the source to the destination, providing a high level of security.

- *Explanation:*

Encryption protects video streams from interception and eavesdropping, maintaining the confidentiality and privacy of the content during transmission.

➢ *Data Integrity [26]:*

- *Verifies that Video Streams are not Tampered with During Transmission:*

Data integrity mechanisms use techniques like hash functions to ensure that video streams arrive at their destination unchanged.

- *Error Detection:*

These mechanisms detect any alterations or corruption that may occur during transmission, allowing for the identification of tampered data.

- *Explanation:*

Data integrity safeguards confirm that video streams have not been altered or tampered with en route, preserving the authenticity and trustworthiness of the content.

- *Explanation:*

Security measures are of paramount importance in IoT-SPANs to protect video streams and IoT data from unauthorized access, eavesdropping, and tampering:

- *Authentication and Authorization:*

These mechanisms establish who can access video streams and what actions they are allowed to perform. They prevent unauthorized devices or users from accessing sensitive video content.

- *Encryption:*

Encryption ensures that video data remains confidential during transmission, safeguarding it from interception and unauthorized access. This is particularly critical when video streams contain sensitive information.

- *Data Integrity:*

Data integrity checks guarantee that video streams are received in their original, untampered state. Any unauthorized modifications or corruption can be detected and addressed, maintaining the integrity of the video content.

Implementing robust security measures is essential in IoT-S PAN video streaming to protect against potential threats and vulnerabilities, ensuring the privacy, confidentiality, and reliability of video streams and associated data.

H. Scalability and Load Balancing:

➢ *Load Balancing Algorithms [24]:*

- *Distribute Streaming Load:*
 Load balancing algorithms are responsible for distributing the streaming load evenly across the available devices and resources within the IoT-SPAN network.

- *Prevent Congestion:*
 By distributing the load, these algorithms help prevent network congestion and resource bottlenecks, ensuring that video streaming remains smooth and responsive.

Adaptive load balancing: Some load balancing mechanisms adapt in real-time to changing network conditions and device capabilities to optimize resource utilization.

- *Explanation:*
 Load balancing mechanisms are essential for ensuring that the network can handle the streaming load efficiently, preventing performance degradation and disruptions due to congestion.

➢ *Edge Computing [29]:*

- *Offload Processing to Edge Devices:*
 Edge computing involves moving data processing and computation closer to the edge of the network, reducing the need for centralized data centers.

- *Enhancing Scalability:*
 Edge computing enhances scalability by allowing edge devices, such as smartphones and IoT sensors, to process video data locally, reducing the load on centralized servers and network infrastructure.

- *Reducing Latency:*
 By processing data closer to the source or the user, edge computing reduces latency, ensuring real-time responsiveness in video streaming applications.

- *Explanation:*
 Edge computing is a key strategy for enhancing scalability in IoT-SPANs. It allows for efficient local processing of video data, reducing the strain on central resources and improving overall system performance.

- *Explanation:*
 Scalability and load balancing mechanisms are crucial for ensuring that IoT-SPANs can handle varying workloads and maintain the quality of video streaming:

- *Load Balancing Algorithms:*
 These mechanisms ensure that the streaming load is evenly distributed across available devices and resources, preventing congestion and optimizing resource utilization. Adaptive load balancing can further optimize performance by responding to changing network conditions.

- *Edge Computing:*
 Edge computing offloads processing tasks to edge devices, reducing the reliance on centralized resources. This enhances scalability by distributing computational loads and reduces latency by processing data closer to the source, improving the overall efficiency of video streaming in IoT-SPANs.

Efficient scalability and load balancing are essential in dynamic IoT-SPAN environments, where the number of devices and data traffic can fluctuate. These mechanisms ensure that the network remains responsive, reliable, and capable of delivering high-quality video streaming experiences as the network expands or experiences variable workloads.

I. Energy Efficiency:

➢ *Power Management:*

- *Optimizes Power Usage in Smartphones and IoT Devices:*
 Power management strategies aim to maximize the efficiency of power consumption in both smartphones and IoT devices to extend their battery life.

- *Dynamic Power Profiles:*
 These strategies may involve dynamically adjusting device settings, such as screen brightness, CPU frequency, and network activity, based on workload and available power.

- *Background Processes:*
 Managing background processes and network connections to minimize power drain during periods of inactivity.

- *Explanation:*
 Power management is essential for preserving battery life in energy-constrained devices like smartphones and IoT sensors, ensuring they can operate for extended periods without recharging.

➢ *Energy-Aware Routing [11]:*
 Routing algorithms that consider device power levels: Energy-aware routing algorithms take into account the power levels of devices when making routing decisions within the IoT-SPAN network.

- *Optimizing Routes:*
 These algorithms may prefer routes that involve devices with higher remaining battery life to reduce the risk of network partition or node failure.

- *Balancing Energy Consumption:*
 Energy-aware routing aims to distribute data transmission tasks in a way that balances the energy consumption among devices, preventing premature battery depletion.

- *Explanation:*

Energy-aware routing is critical in IoT-SPAN scenarios where devices operate on limited battery power. It helps prolong device lifespan and maintain network connectivity by intelligently managing routing decisions based on available power.

- *Explanation:*

Energy efficiency strategies are crucial in IoT-SPAN environments, especially for devices with limited battery capacity, to ensure reliable and long-lasting operation:

- *Power Management:*

Optimizing power usage in smartphones and IoT devices through dynamic adjustments and background process management is essential for extending battery life. It allows devices to operate efficiently and perform necessary tasks while conserving power during periods of inactivity.

- *Energy-Aware Routing:*

Routing algorithms that consider device power levels help ensure that energy-constrained devices are not overburdened and that routes are selected to minimize the risk of network disruptions due to device battery depletion. This approach contributes to the overall stability of the IoT-SPAN network.

By implementing these energy-efficient strategies, IoT-SPANs can maximize the operational lifespan of devices and maintain network connectivity even in resource-constrained scenarios, thereby enhancing the overall reliability and longevity of the network.

J. Content Delivery and Caching:

➢ *Content Delivery Networks (CDNs) [22]:*

Cache and deliver popular content closer to end-users: CDNs consist of a distributed network of servers strategically placed in various geographical locations. They store and serve frequently requested video content from servers that are physically closer to end-users.

- *Reducing Latency:*

CDNs significantly reduce latency by minimizing the distance data must travel. When a user requests video content, it is delivered from the nearest CDN server, improving streaming performance.

- *Load Distribution:*

CDNs distribute the load across their server network, preventing congestion and ensuring that video streams remain accessible even during peak usage.

- *Explanation*:

CDNs are fundamental for optimizing video streaming performance by reducing latency, enhancing content availability, and efficiently handling high-demand video content.

➢ *Local Caching [10]:*

- *Store Video Content on Nearby Devices:*

Local caching involves storing video content on nearby devices within the IoT-SPAN network.

- *Minimizing Data Transfer and Latency:*

By accessing cached content locally, devices can reduce the need for data transfer over long distances, minimizing latency and conserving network bandwidth.

- *Adaptive Caching:*

Local caching systems may adaptively select which content to cache based on usage patterns, device capabilities, and available storage.

- *Explanation:*

Local caching within the IoT-SPAN network can significantly enhance video streaming efficiency by reducing data transfer distances and improving the overall user experience.

- *Explanation:*

Content delivery and caching mechanisms are instrumental in enhancing video streaming efficiency within IoT-SPANs:

- *CDNs (Content Delivery Networks):*

CDNs reduce latency by serving video content from servers that are geographically closer to end-users. This minimizes data transfer distances, optimizes content availability, and ensures that video streams remain accessible and responsive, even during high-demand periods.

- *Local Caching:*

Local caching on nearby devices within the IoT-SPAN network minimizes data transfer and latency by allowing devices to access frequently requested video content locally. Adaptive caching ensures that the most relevant content is stored based on usage patterns and device capabilities.

Both CDNs and local caching contribute to improved video streaming efficiency, reduced network congestion, and enhanced user experience by ensuring that video content is readily available and delivered with minimal delay. These mechanisms are particularly valuable in scenarios where low-latency and efficient data transfer are critical, such as real-time video streaming in IoT-SPANs.

K. Application Scenarios:

➢ *Surveillance [6]:*

Streaming video from IoT cameras to smartphones for monitoring: Surveillance scenarios involve the streaming of video feeds from IoT cameras or sensors to smartphones for real-time monitoring and security purposes.

- *Live Video Access:*

Users can access live video streams from cameras placed in homes, businesses, or public areas to monitor activities remotely.

- *Event Detection:*

Surveillance applications often incorporate video analytics to detect specific events or anomalies, alerting users when predefined conditions are met.

- *Explanation:*

Surveillance applications rely on video streaming for real-time monitoring, security, and event detection, enhancing situational awareness and safety.

➢ *Remote Control [6]:*

Controlling IoT devices remotely via video feedback: In remote control scenarios, video streaming provides visual feedback that allows users to control and interact with IoT devices from a distance.

- *Visual Feedback:*

Users can view live video feeds from IoT devices like drones or robots and make informed decisions for remote control.

- *Enhanced User Experience:*

Video feedback enhances user engagement and control precision, particularly in applications where visual context is crucial.

- *Explanation:*

Remote control applications leverage video streaming to enable users to remotely operate and manage IoT devices, expanding their capabilities and reach.

➢ *Healthcare [16]:*

- *Streaming Medical Data and Video for Remote Patient Monitoring:*

Healthcare applications involve the streaming of medical data and video feeds from patients to healthcare professionals for remote patient monitoring.

- *Continuous Monitoring:*

Patients can use IoT devices to transmit vital signs, medical images, or video of their condition to healthcare providers.

- *Telemedicine:*

Video streaming supports telemedicine consultations, allowing healthcare professionals to assess patients remotely and provide medical guidance.

- *Explanation:*

Healthcare applications heavily rely on video streaming to facilitate remote patient monitoring, telehealth consultations, and the timely sharing of critical medical information.

- *Explanation:*

Different application scenarios within IoT-SPANs require tailored video streaming solutions that align with specific use case requirements:

- *Surveillance:*

Surveillance applications focus on real-time monitoring, security, and event detection. They rely on video analytics and live video access to enhance situational awareness and safety.

- *Remote Control:*

Remote control scenarios use video streaming to provide visual feedback, enabling users to interact with and control IoT devices from a distance. This enhances user engagement and control precision.

- *Healthcare:*

Healthcare applications leverage video streaming for remote patient monitoring, telemedicine consultations, and the continuous transmission of medical data. Video streaming supports timely medical assessments and the sharing of critical patient information.

Each application scenario has unique demands and objectives, which influence the design and implementation of video streaming solutions within IoT-SPANs. Tailoring video streaming to specific use cases ensures that the technology effectively meets the needs of users and stakeholders in these diverse scenarios.

L. Middleware and Protocols [25]:

➢ *MQTT (Message Queuing Telemetry Transport) and CoAP (Constrained Application Protocol):*

- *Lightweight Communication Protocols for IoT:*

MQTT and CoAP are designed for resource-constrained IoT devices. They are lightweight, efficient, and well-suited for low-power, low-bandwidth, and intermittent connectivity scenarios.

- *Publish-Subscribe Model:*

MQTT operates on a publish-subscribe model, enabling efficient data distribution to multiple subscribers. CoAP follows a request-response model for efficient client-server communication.

- *Scalability:*

Both protocols are scalable and can accommodate a large number of devices, making them suitable for IoT-SPANs with diverse device types.

- *Explanation:*

MQTT and CoAP serve as essential communication protocols within IoT-SPANs, enabling efficient and reliable data exchange between devices and the central network.

➢ *Fog/Edge Computing Middleware:*

- *Middleware for Managing Data and Computation at the Edge:*

Fog and edge computing middleware manage data processing, storage, and computation at the edge of the network, closer to IoT devices.

- *Decentralized Processing:*

Middleware at the edge enables decentralized data processing, reducing latency and bandwidth consumption by performing computations closer to data sources.

- *Optimizing Resource Usage:*

Edge middleware optimizes resource usage by distributing computational tasks intelligently across edge devices, ensuring efficient use of computing power and network bandwidth.

- *Explanation:*

Fog and edge computing middleware are instrumental in optimizing data processing and computation within IoT-SPANs, enhancing efficiency, reducing latency, and improving the overall performance of the network.

- *Explanation:*

Middleware and communication protocols play a critical role in facilitating data exchange and computation within IoT-SPANs:

- *MQTT and CoAP:*

Lightweight communication protocols like MQTT and CoAP are well-suited for resource-constrained IoT devices. They enable efficient and reliable data transmission in scenarios where bandwidth and power consumption are critical considerations. MQTT's publish-subscribe model and CoAP's request-response model offer flexibility for different communication patterns.

- *Fog/Edge Computing Middleware:*

Middleware designed for fog and edge computing extends the capabilities of IoT-SPANs by enabling data processing and computation at the edge of the network. This approach reduces latency, optimizes resource usage, and enhances the overall efficiency of IoT applications.

Selecting the appropriate middleware and communication protocols depends on the specific requirements and constraints of the IoT-SPAN network, including device capabilities, communication patterns, and the need for edge computing capabilities. These choices significantly impact the network's performance and ability to meet user and application needs.

M. Data Analytics and Machine Learning [28]:

➢ *Analytics:*

Processing and analyzing video data for insights:

Analytics in the context of video streaming involves processing and analyzing video content to extract valuable insights, detect patterns, and generate data-driven recommendations.

- *Decision Support:*

Video analytics can provide decision support by offering real-time information and alerts based on the analysis of video streams. This is valuable in applications such as surveillance and security.

- *Optimizing Content Delivery:*

Analytics can be used to monitor network performance, viewer behavior, and content quality, allowing for the optimization of content delivery and the enhancement of user experiences.

- *Explanation:*

Video analytics improve video streaming by adding a layer of intelligence to the process, enabling real-time decision-making, content optimization, and insights generation from video data.

➢ *Machine Learning:*

- *Implementing AI for Video Content Analysis and Pattern Recognition:*

Machine learning, particularly artificial intelligence (AI) algorithms, is used for in-depth video content analysis, recognizing objects, faces, actions, and patterns within video streams.

- *Automation:*

Machine learning models can automate tasks such as content tagging, object tracking, and anomaly detection in real-time video feeds.

- *Personalization:*

Machine learning can be applied to personalize video content recommendations based on user preferences and behavior.

- *Explanation:*

Machine learning enhances video streaming by automating content analysis, enabling advanced video content recognition, and personalizing content recommendations for users.

- *Explanation:*

Data analytics and machine learning are essential components that enhance video streaming in IoT-SPANs:

- *Analytics:*

Video analytics processes and analyzes video data to extract valuable information and provide real-time insights. This is particularly useful for decision support, content optimization, and enhancing the quality of the video streaming experience.

- *Machine Learning:*

Machine learning, powered by artificial intelligence, enables advanced video content analysis, automation of tasks, and personalization of video content recommendations. It plays a pivotal role in automating tasks, recognizing patterns, and enhancing the overall user experience.

Together, data analytics and machine learning bring intelligence and automation to video streaming within IoT-SPANs, enabling real-time decision-making, content optimization, and personalized user experiences. These capabilities are valuable in a wide range of IoT applications, from surveillance to content delivery and beyond.

N. User Experience:

- *User Interfaces:*

Smartphone apps and interfaces for video streaming control: User interfaces (UIs) for video streaming on smartphones play a crucial role in user experience. These UIs provide controls for starting, pausing, adjusting video playback, and accessing content libraries.

- *Responsive Design:*

User interfaces are designed to be responsive, ensuring that they work seamlessly across various smartphone screen sizes and orientations.

- *Intuitive Navigation:*

User-friendly navigation and intuitive controls enhance the user experience by making it easy for users to find and enjoy video content.

- *Explanation:*

User interfaces are the primary means through which users interact with video streaming applications on smartphones. Well-designed UIs contribute to a positive user experience by providing ease of use and accessibility.

- *User Feedback:*

- *Gathering User Feedback for Quality Improvements and Customization:*

User feedback mechanisms, such as ratings, reviews, and surveys, allow users to provide input on their video streaming experiences.

- *Quality Improvements:*

User feedback is invaluable for identifying issues with video quality, streaming performance, or user interface design. It helps streaming services make continuous improvements.

- *Customization:*

User feedback can inform personalized content recommendations and customization options, tailoring the video streaming experience to individual preferences.

- *Explanation:*

Collecting and acting on user feedback is essential for addressing user concerns, enhancing video streaming quality, and providing tailored experiences that meet individual preferences.

- *Explanation:*

User experience considerations are critical for ensuring user satisfaction and usability in video streaming applications within IoT-SPANs:

- *User Interfaces:*

Well-designed user interfaces for smartphone apps and video streaming control enhance user engagement by providing responsive and intuitive controls. They ensure that users can easily access and enjoy video content on their devices.

- *User Feedback:*

Gathering user feedback allows video streaming services to continuously improve their offerings. Feedback mechanisms enable quality enhancements, customization options, and the identification of areas where user experience can be optimized.

User experience is central to the success of video streaming applications, and by prioritizing user interfaces and feedback mechanisms, IoT-SPANs can provide a seamless and tailored experience for users, ultimately enhancing user satisfaction and retention.

O. Regulatory and Privacy Considerations [3]:

- *Data Privacy:*

- *Compliance with Data Protection Regulations and Policies:*

Data privacy regulations, such as GDPR (General Data Protection Regulation) in Europe or CCPA (California Consumer Privacy Act) in the United States, dictate how personal data is collected, processed, and protected.

- *User Consent:*

Ensuring that users provide informed consent for data collection and processing, especially in video streaming applications that may involve personal information.

- *Data Encryption:*

Implementing strong encryption measures to protect user data during transmission and storage.

- *Explanation:*

Data privacy compliance is essential to protect user information and maintain trust. It involves adhering to legal requirements and best practices for data handling within video streaming applications.

- *Spectrum Regulations:*

- *Compliance with Spectrum Allocation and Usage Rules:*

In wireless communication scenarios, compliance with spectrum regulations is crucial. These rules govern the allocation and use of radio frequencies to avoid interference and ensure efficient spectrum utilization.

- *Frequency Licensing:*

Adhering to licensing requirements for specific frequency bands when using wireless technologies for video streaming.

- *Interference Avoidance:*

Ensuring that video streaming operations do not interfere with other licensed or unlicensed wireless services in the same spectrum.

- *Explanation:*

Spectrum regulations compliance is vital in wireless video streaming scenarios to maintain reliable communication and avoid disruptions due to interference.

- *Explanation:*

Regulatory and privacy considerations are fundamental for ensuring that IoT-SPAN video streaming solutions operate within the bounds of legal and operational requirements:

- *Data Privacy:*

Compliance with data protection regulations and policies is essential to safeguard user privacy. This involves obtaining user consent for data processing, implementing robust data encryption measures, and adhering to legal requirements for data handling.

- *Spectrum Regulations:*

In wireless communication scenarios, compliance with spectrum allocation and usage rules is crucial for preventing interference and ensuring reliable video streaming. This includes obtaining the necessary frequency licenses and operating within the allocated spectrum bands.

By addressing regulatory and privacy considerations, IoT-SPAN video streaming solutions can operate legally, protect user privacy, and maintain the quality and reliability of video streaming services while adhering to relevant legal and operational guidelines.

III. DISCUSSION

The proposed taxonomy" serves as a valuable tool for dissecting and understanding the intricacies of video streaming in Smartphone Ad Hoc Networks (SPAN) within the Internet of Things (IoT) ecosystem. This taxonomy provides a structured framework that facilitates discussion, analysis, and decision-making in the design and optimization of video streaming solutions for IoT-SPAN scenarios. Here, we delve into the significance and implications of key components within the taxonomy:

➢ *Network Architecture and Communication Technologies:*

Understanding the choice of network architecture is pivotal, as it dictates the available infrastructure and network dynamics. IoT-SPANs can leverage existing infrastructure or operate in infrastructure-less environments, which greatly influences design choices. The taxonomy highlights the importance of selecting the most suitable communication technologies (e.g., Wi-Fi, Bluetooth, cellular) based on the specific IoT-SPAN context.

➢ *Routing and Video Streaming Protocols:*

Routing protocols play a critical role in establishing efficient data paths within IoT-SPANs, affecting the overall performance of video streaming. The taxonomy distinguishes between proactive and reactive routing protocols, allowing practitioners to make informed decisions based on the network's mobility and traffic patterns. Additionally, the inclusion of video streaming protocols (e.g., HLS, DASH, RTP) ensures compatibility with different streaming requirements and standards.

➢ *Quality of Service (QoS) and Security:*

Ensuring a high-quality video streaming experience is essential in IoT-SPANs. The taxonomy introduces QoS considerations such as bandwidth management, quality metrics, and error handling techniques. Security measures are paramount in protecting video streams and sensitive IoT data. Proper authentication, encryption, and data integrity mechanisms are vital to safeguarding the network.

➢ *Scalability, Energy Efficiency, and Content Delivery:*

Scalability is addressed by load balancing algorithms and edge computing strategies, allowing IoT-SPANs to efficiently accommodate varying loads and device capabilities. Energy efficiency is crucial, given the often resource-constrained nature of IoT devices and smartphones. The taxonomy emphasizes power management and energy-aware routing to optimize battery life. Content delivery mechanisms, including CDNs and local caching, are essential for minimizing latency and enhancing the streaming experience.

➢ *Application Scenarios and Data Analytics:*

IoT-SPAN video streaming caters to diverse application scenarios, such as surveillance, remote control, and healthcare. Understanding these scenarios helps tailor solutions to specific needs. The taxonomy also acknowledges the potential of data analytics and machine learning for real-time analysis of video content, offering valuable insights for decision-making.

➢ *User Experience and Regulatory Compliance:*

User experience considerations, including user interfaces and feedback mechanisms, are essential for ensuring satisfaction and usability. Additionally, compliance with regulatory requirements and standards is crucial, encompassing data privacy, spectrum regulations, and other legal considerations.

By providing a structured taxonomy, this framework fosters a common language and understanding among stakeholders in the IoT-SPAN video streaming domain. It aids in the selection of appropriate technologies and strategies for addressing the unique challenges and opportunities within IoT-SPANs. Furthermore, the taxonomy can serve as a basis for research, development, and innovation, helping practitioners navigate the complex landscape and drive advancements in video streaming solutions tailored to the IoT-SPAN environment.

IV. CONCLUSION

➢ *The "Navigating the IoT-SPAN Video Streaming Landscape:*

A Comprehensive Taxonomy" provides a systematic and structured framework for comprehending the intricate world of video streaming within Smartphone Ad Hoc Networks (SPAN) in the context of the Internet of Things (IoT). This taxonomy encompasses a wide array of critical dimensions, ranging from network architecture and communication technologies to security, scalability, user experience, and regulatory compliance. As we conclude our exploration of this taxonomy, several key takeaways emerge:

- *Holistic Understanding:*

The taxonomy offers a holistic perspective on the multifaceted aspects of video streaming in IoT-SPANs. It encourages stakeholders, including researchers, developers, and practitioners, to consider the full spectrum of factors that influence the design, deployment, and optimization of video streaming solutions.

- *Tailored Solutions:*

IoT-SPANs are diverse and dynamic, serving various application scenarios and deployment contexts. The taxonomy empowers decision-makers to select and adapt technologies, protocols, and strategies that align with the unique demands of each scenario, be it surveillance, remote control, healthcare, or beyond.

- *Efficiency and Quality:*

Quality of service and energy efficiency are central concerns in IoT-SPAN video streaming. This framework guides the implementation of techniques for efficient bandwidth utilization, real-time analytics, and energy-aware routing, all aimed at delivering high-quality streaming experiences while conserving resources.

- *Security and Compliance:*

As IoT-SPANs handle sensitive data and interact with various devices, security and regulatory compliance are paramount. The taxonomy underscores the importance of robust security measures, including authentication, encryption, and data integrity, to safeguard video streams and IoT data.

- *Innovation and Research:*

By providing a structured foundation, the taxonomy encourages innovation and research in IoT-SPAN video streaming. It serves as a reference point for exploring new solutions, improving existing ones, and addressing emerging challenges in this evolving landscape.

- *In Conclusion, the "Navigating the IoT-SPAN Video Streaming Landscape:*

A Comprehensive Taxonomy" is a valuable resource for those navigating the dynamic and complex world of video streaming in IoT-SPANs. It equips stakeholders with the knowledge and insights necessary to make informed decisions, develop effective solutions, and contribute to the advancement of video streaming technologies that cater to the diverse and expanding IoT-SPAN ecosystem. As this domain continues to evolve, this taxonomy stands as a foundational tool for shaping its future trajectory.

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