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# Exploring Energy Consumption Issues for video Streaming in Mobile Devices: a Review

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***Abstract—****The proliferation of high-end mobile devices, such as smart phones, tablets, together have gained the popularity of multimedia streaming among the user. It is found from various studies and survey that at end of 2020 mobile devices will increase drastically and Mobile video streaming will also grow rapidly than overall average mobile traffic. The streaming application in Smartphone heavily depends on the wireless network activities substantially amount of data transfer server to the client. Because of very high energy requirement of data transmitted in wireless interface for video streaming application considered as most energy consuming application. Therefore to optimize the battery usage of mobile device during video streaming it is essential to understand the various video streaming techniques and there energy consumption issues in different environment. In this paper we explore energy consumption in mobile device while experiencing video streaming and examine the solution that has been discussed in various research to improve the energy consumption during video streaming in mobile devices . We classify the investigation on a different layer of internet protocol stack they utilize and also compare them and provide proof of fact that already exist in modern Smartphone as energy saving mechanism.*

***Keywords****— **power consumption, video streaming, internet protocol stack .***

## I. INTRODUCTION

Now a days video content is gradually more consumed by mobile devices [1]. As it shown in below fig. 1 by the end of 2020, the number of such mobile devices will exceed tremendously and Mobile video usage will grow at a CAGR of 62 percent between 2015 and 2020, higher than the overall average mobile traffic CAGR of 53 percent" [1]. Figure 1 shows a growth rate of video usage.At the same time, it is very important to fulfill user expectation in term of playback quality and battery usage in mobile device while streaming the video.

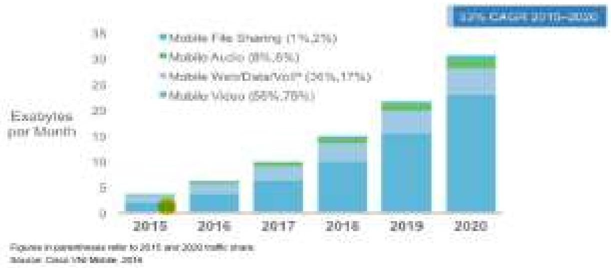


*Fig.1*

In mobile video streaming, it is essential that user can experience the best quality with optimized energy consumption. There are so many challenges for video streaming services while transmitting the video content to the streaming client for smooth playbacks like clients with the different type of connectivity, initial playback delay, and the bandwidth variation between a server and a client [2]. While playing multimedia streaming content, energy consumption of smartphones is also considered as an important issue and consequently, a significant number of research work focused on reducing the energy consumption of the mobile device.

The major consumption of energy in any mobile devices is due to both display on and decoding the multimedia. Energy consumption due to decode audio or video depends on the computational complexity of algorithm used by the codec and/or compression technique used for encoding.

There is various technique used by streaming services while sending video content to mobile devices, such as rate throttling, buffer adaptive streaming, rate adaptive streaming over HTTP encoding rate streaming, and fast caching. In Encoding rate streaming scheme the content is sent at encoding rate. While in Throttling and fast caching delivering of video content has a higher rate than the encoding rate. Playback buffer status of the client has used in Buffer adaptive mechanisms. In this, the client receives content from the server only when playback buffer exhausted to a specific limit. Initially, whole content has been downloaded in Fast caching technique. while Rate adaptive mechanisms adjust with video quality as per the end-to-end bandwidth between a server and the client. In some research, it analyzes the merits of these streaming techniques from the server performance point of view. For example, it is observed that fast caching minimize start-up delay at the client and protect against bandwidth fluctuation, but it also consumes a lot of recourses like memory and CPU at the streaming server [2]. There is a lot of studies made to understand streaming technique but still, some research are required from the perspective of mobile devices and power consumption. Although many studies show the traffic pattern of video streaming with various mobile devices but it is still the part of research to find the different optimal technique in different context. The main aim of these streaming techniques is the smooth delivery of quality video content with reduced energy consumption to the user. It is essential to know what satisfies the user demand before one can design a streaming service in terms of quality of experience and battery life of their Smartphone.

As most of the energy consumption take place in display and decoding and wireless interfaces can equally drain the same amount of energy while running video streaming applications in mobile devices. The main focus of the study is to identify communication energy spent by mobile devices while receiving and playing multimedia content. "It has been observed in a study that Wi-Fi interface requires approximate three times of the energy needed to decode video content [4], [5], whereas 3G interface uses approximately five times of the decoding energy" [2]. The interface has high energy consumption because due to continuous flow of traffic the wireless radio is powered on most of the time during streaming. There are many components involve at the various layer of internet protocol stack like wireless radios operate at the physical layer, at the same time their power consumption highly depends on the wireless interface management or usage at the different technique implemented at higher layers of the Internet protocol suite, such as at link layer, network, transport and application layer . Therefore, all these layers should be included in the minimization of energy consumption.

The classification of the investigation is done according to the Internet protocol layers and research solution is shown Table 1. At physical layer, different modulation schemes are considered. Link layer solutions apply energy-aware traffic scheduling for several wireless clients and manage wireless interface at the mobile devices and. Link layer solutions are divided into standard and non-standard techniques. Cross-layer solutions use a combination of different protocols that operate on various layers or at least use information from different layers while optimizing the behavior of a protocol of another layer. We classify them according to the need of their operational environment (client, server, or proxy). Application layer techniques use scalable video coding (SVC), transcoding and content selection to minimize energy consumption of the mobile devices.

*Table.1: Research Solution At Different Layer*

| **Internet Protocol Stack** | **Research solution** |
|---|---|
| Physical layer | Dynamic Modulation Scaling (DMS),<br>Quadrature Amplitude Modulation (QAM),<br>Frequency Shift Keying (FSK) |
| Link layer[LL] | Wi-Fi Access (IEEE 802.11 Standards),<br>PSM-A ,Enhanced Distributed Channel Access (EDCA) Radio Resource Control protocol |
| Cross-layer | **Client centric solution**<br>Self-Tuning Power Management Traffic Prediction, Scheduling Traffic among Multiple Wireless Interfaces(cool spot) Cool-Tether Proxy or AP Assisted Solutions Traffic shaping, Scheduling Bursty traffic Server-Assisted Solutions AB-PSM |
| Application layer | Scalable Video Coding ,Content Selection,HTTP Rate Adaptive Streaming,Media Transcoding |

## II. VIDEO STREAMING AND TECHNIQUES

Video streaming is the act of transmitting compressed (typically) video across a private or public network (like the Internet, a LAN, satellite, or cable television) to be uncompressed and played on a computing device (such as a TV, smart phone or computer). Now a day's mobile streaming services send content using HTTP over TCP. Smartphone users can access these services using either a native app or a browser. The browser may use a Flash, HTML5 or Microsoft Silverlight player to play the video. There are different quality of played by video services generally referred as p-notation, such as 240p, which refers to the resolution of the video. 240p usually refers to 360x240 resolutions. Different services use also low, standard, and high definition (LD, SD, HD) notations but the resolutions that each one refers to varies between services. For handling video streaming system require video container. The container is a metafile format whose specification describes how different elements of data and metadata coexist in a computer file. A video container formats can support multiple audio and video streams, and various required information of video along with the synchronization information needed to play back the various streams together. For example, container formats exist for optimized, low-quality, internet video streaming which differs from high-quality streaming requirements. The default container for the player is MP4, WebM, and X-FLV. The native apps of Netflix players play are videos.

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WebM and X-FLV are the default containers for the HTML5, and Flash player respectively while YouTube, Dailymotion and Vimeo also play MP4 and 3GPP videos. Table 2 shows the examples of different video services, the types of video players, video qualities, and containers.

*Table.2: Different video services, the types of video players, video qualities, and containers*

| | |
|---|---|
| **Streaming Services** | YouTube, Vimeo, Dailymotion, ShoutCast, Netflix Hulu ESPN Player, BBC iPlayer |
| **Players** | Native Application, Flash, and HTML5 |
| **Video Quality** | High Definition (720-1080p) Standard definition (270-480p), low Defination (240p), |
| **Containers** | Ismv, , X-FLV, 3GPP,EVO, MP4, WebM |

Modern streaming services apply a number of techniques to deliver multimedia to the streaming clients. The main aim of all streaming service to provide uninterrupted playback while occurrence of bandwidth fluctuation and jitter. To achieve this most of the streaming service first, buffer the video content at the client end. This buffered content is noticeable to the user as start up delay and known as Fast Start. The initially buffered data is downloaded using all the available bandwidth, while the rest of the video is downloaded using one of the following techniques:

i. **Bitrate streaming:**
"Bitrate streaming technique is used to transmit the data at the encoding rate of the stream. A streaming period start with Fast Start and then the player accept data at the encoding rate from the server session. In this case controlling of rate is handled by streaming client"[3] .YouTube players, the Daily motion player use Bitrates streaming technique.

ii. **Throttling:** In this technique service provider purposely slowing of transmission rate. It can be used to vigorously control the user's upload and download rates on video streaming
Throttling also refers to the technique which limit the delivery content rate to a client but which has always higher rate than the encoding rate. The transmission rate is controlled by the server.

iii. **ON-OFF (Buffer Adaptive Streaming):**ON-OFF technique is based on playback buffer status of a player. When the player has enough content to play, it informs the server to stop the sending the data. The server restart data transmission only when the buffer falls beneath a threshold at the client side.

iv. **DASH or (Rate Adaptive Streaming.)**
Above discussed streaming technique, a client player can play a video of a particular quality ( i.e HD or SD or LD )during a streaming session. We change the quality by interrupting session. While DASH, allows the player to switch the stream quality on the fly to adjust bandwidth fluctuations. "The Vimeo player in iPhone 4S uses Apple's version of DASH called HTTP Live Streaming (HLS). The player receives content in chunks and each chunk can be requested separately by specifying the quality"[5].

v. **Fast Caching.**
Fast Caching refers to downloading the whole video using the utmost available bandwidth. The client player have to maintain large growing buffer and it decodes content at the encoding rate.

## III. LAYER BASED ANALYSIS

**Physical layer**

When we apply the energy usage optimization concept it would be helpful to all type of application in system. In physical layer, energy depletion is evaluated on the basis of amount of the carrier channel capacity and the transmission distance. Therefore, study shows that rather than utilizing the maximum capacity during a streaming session, solutions it is better to give much emphasis to tune the modulation level to limit the transmission rate according to the actual bit rate of the content dynamically. This is also known as Dynamic Modulation Scaling (DMS). "DMS is applied such that the lower the bit rate, the lower is the modulation level and the lower is energy consumption".[15] It is also observed that , the energy per bit is reduced by increasing the transmission time. At the same time it is not sufficient to change the modulation level, it may not always give the smallest energy consumption because energy consumption also depends on the transmission distance [16]. "Some time, it may also require changing the modulation scheme as well. For example , if the transmission distance is more than a threshold, reducing modulation level does not reduce energy consumption using Quadrature Amplitude Modulation" (QAM), rather energy consumption increases. In such a scenario "Frequency Shift Keying (FSK) is more energy efficient"[.16] However, it is very impractical to change modulation scheme or modulation level dynamically. The reason while doing so negotiation between the transmitter and the receiver is mandatory, the implementation of a such scheme requires careful reconfiguration at the receiver in order to operate with proper modulation scheme or level and hence there is protocol overhead. [15].

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**LINK LAYER**

To improve the energy efficiency in mobile devices at this layer large number of solution has being proposed .There are different classes of solution for Wi-Fi and Cellular network.

**Wi-Fi Access (IEEE 802.11 )**

"IEEE 802.11 interfaces has default power saving mechanism called power saving mode (PSM)" [17]. Using PSM a mobile device regularly awakes to check whether it has any content to transmit/receive. Otherwise, the interface keep on sleep mode. "When the interface is in sleeping mode , the access point (AP) store the arriving data for the client. When the client wakes up, it retrieves the stored data by sending PS-Poll frame to the AP. PSM helps to optimize the energy consumption only when there is regularity in the distribution of multimedia traffic" [19]. However, modern smartphones use a modified version of PSM called PSM Adaptive (PSM-A). "PSM-A forces the interface to stay in active mode for a few hundred milliseconds after transmitting or receiving packets" [2]. However, still PSM is more better than PSM-A .

When multiple devices compete for the same wireless channel called Channel contention cause lots of energy wastage in mobile devices .To handle this situation the modified version 802.11e called Enhanced Distributed Channel Access (EDCA).In this case when there is bulk of transfer in multimedia traffic EDCA will set channel access priority . "Another version EDCA Unscheduled Automatic Power Save Delivery (UAPSD) which is suitable when exchange traffic is duplex such as VoIP". [4]

**Modified Power saving Mechanism**

A significant number of studies have done to improve the default behaviour of Power Saving Mechanism. Researcher tries to maximize utilization of inactive period in between data packets to put the Wi-Fi interface in sleep mode without acquiring excessive delay. µPSM tries to take the benefit of small duration between the retransmission of a frame. Although, these solutions are not that much appropriate with multimedia streaming applications since such small idle periods are difficult to measure while exchange of data is very high.

**Contention-free Wi-Fi scheduling**

When Wi-Fi access points are getting deployed heavily it is very difficult to avoid energy waste due to interference and channel contention. Many solutions suggested to reserve a time slot for each individual connected client [3,4]. All clients have given a reserved time slot for contention free transmission with other clients. These types of novel solutions are very common and thus appropriate to decrease energy consumption for any type of traffic and thus video streaming. These time slicing technique need to update power saving mode and consequently which need to update at both the ends .i.e. client device and the AP which makes them difficult to deploy in practice.

**Cellular Network Access (3GPP Standards)**

In cellular network interface (3G or LTE) Radio Resource Control protocol is used for state transition and power management of smart.

**HSPA/3G**

In case of 3G, the Radio Resource Control has four states [16]. The states are CELL_DCH, CELL_FACH, CELL_PCH, IDLE. Every state consists of current consumption state, transitions, inactivity timers. In CELL_DCH state, for optimization of throughput latency a dedicated data channel is assign to mobile device. In CELL_FACH state the channel is used for sharing purpose among the mobile device since it has less data capacity. In CELL_PCH state enables to page a mobile device. IDLE state disconnect from RRC. There is no standard fixed value is given to inactivity time generally operators take the values in some range in seconds. In these inactivity periods, there is no exchange of data and the energy spent is called as tail energy [16, 17]. However, "modern smart phones try to avoid long tail energy using a modified standard called Fast Dormancy (FD) with an inactivity timer of 3-5 seconds [4]. FD enables a mobile device directly to switch from CELL_DCH to CELL_PCH or IDLE state depending on the standard implemented in the smart phone and whether network supports CELL_PCH or not".

**LTE**

LTE RRC protocol has of only two states: RRC_IDLE and RRC_CONNECTED. In this case there is a RRC inactivity timer which responsible to control the transition from connected to the idle state. "In LTE to enable low power state in mobile device the discontinuous transmission and reception denoted by DTX/DRX. Connected DRX state is known cDRX. The transition of one state to another .i.e. RRC_CONNECTED to RRC_IDLE state occur when the RRC inactivity timer expires and the device enters in the paging monitoring mode"[6]. LTE work on two states it requires less signalling due to which energy consumption is less.

Another way to save the energy by changing or configuring Network parameters in Cellular Networks. Numerous works and solutions are present in this scheme but they were not much energy efficient unless some higher layer solution also being to be consider.

**Cross Layer Approaches**

Large Number of energy efficient schemes works rigorously above the link layer. Two main concepts being used at this layer one is multimedia traffic shaping or scheduling a Majority of researcher give the alternate solution to the states of the wireless network interface at the client which include multimedia traffic management at the server, proxy or at the client.

**Client centric**

Mostly the client centric solution based on buffer adaptive method that work on idle period mechanism and traffic prediction that find the idle time period between packet . Generally the client centric solutions use buffer adaptive mechanisms to generate idle periods and traffic prediction mechanisms to identify idle periods between packets. Then they entrust on standard power saving mechanisms or implement their own mechanisms to work out the Wireless Network Interface into sleep state during those idle periods to reduce the energy consumption. Following are the few solution apply by the other technique to handle the client server traffic [3]:

1. **Playback Buffer Management**
   Multimedia services always load a huge amount of the player's playback buffer at the beginning of a streaming session to bear bandwidth fluctuations. A number of solutions use this playback buffer information to reduce the energy consumption there are many solutions provided like fuzzy adaptive approach, Self-Tuning Power Management (STPM).
2. **Traffic Prediction**
   Another known technique is to forecast the arrival time of the arriving traffic. This technique has been widely used to model the energy consumption of wireless network interfaces and to manipulate the Wireless Network Interface to save energy.
3. **Exploiting TCP Flow Control**
   There are also solutions which deal with the TCP flow control that make use of transport protocol property to produce busty traffic via uninterrupted data transmission.
4. **Scheduling Traffic**
   Mobile systems have a number of multiple high speed wireless interface. Another solution is to Schedule traffic among Multiple Wireless Interfaces.

**Proxy or AP Assisted Solutions**

In proxy assisted solution researcher applied number of their techniques in proxy servers, in a Wi-Fi AP or in the cellular network. In this solution playback buffer status will be estimated at the client side and then the solution like traffic shaping or scheduling implemented at the intermediate layer.

**Server-Assisted Solutions**

Instead of providing solution at client or proxy level some researcher provides solution at server side .i.e. server assisted solution. In a this solution, a server uses supplementary buffer such as AB-PSM and add shape traffic into periodic bursts in it[4]. "Server sent data stored into secondary buffer. During this period, a streaming client can keep its Wireless Network Interface into sleep state. When the secondary buffer is filled, the data is sent to the client in a single burst. After, ABPSM was upgraded to a system wide solution in which the server would also select the bit rate, the client would adjust brightness and volume level according to the present battery level" [6]. There are different methods which a client exclusively request the server to transmit busty traffic or a server instruct the client to switch on/off the wireless interface.

**Application layer Mechanisms**

As we discussed in previous section the energy efficient technique do not make changes in multimedia content but in application layer mechanism apply content adaptation to improve battery life. The main aim of content adaptation is to provide mobile devices with different computation mechanism or their display properties. The main concern in this layer is to provide efficient energy decoding scheme considering quality of video and battery life. Few techniques are as below:

- **Scalable Video Coding**
  Scalable Video Coding (SVC) "It has the ability to code a single video stream by using the multiple bit rate transmission channel by organizing the compressed data of video bit streams into layered form. So it is also called as layered video coding. It has base layer which deal with the lowest bit rate stream having the minimum quality, frame rate and spatial resolution. The enhancement layers use to increase the quality of the stream by increasing the frame rate and spatial resolution. This technique has capability to reduce network traffic and computational complexity at the mobile devices, due to which power consumption is reduced" [24].
- **Content Selection**
  Another form of adaptive streaming is Content selection that deals with network and device diversity. "Content based selection of multimedia play a vital role to improve the battery other than display size, bandwidth" [20]. Although, for handling content selection require multiple copies of the same stream are need more recourses, which is overhead.
- **HTTP Rate Adaptive Streaming**
  In HTTP Rate Adaptive Streaming case, service provider divides a transmitting video file into a number of chunks. This chunk is applied on the files of every video quality. There are a numerous of rate adaptive multimedia frame are available , such as "HTTP Live Streaming" [19], smooth streaming, and Adobe's adaptive streaming etc .

- **Media Transcoding**
  Another way to deal with network bandwidth and device diversity for multimedia streaming is transcoding .In this case server contain only one copy of stream and data or content generated as per the need or request of client or receiving end. This mechanism drastically reduces the energy consumption at client side but it require complex computation power which may sometime energy hungry so it is only recommended for mobile device like laptop not for smart phone.

*Table.3: Comparative Analysis of Power Consumption in Various Approach*

| Adaptation Approaches | Wireless Networks | Energy Savings |
|---|---|---|
| SVC[2] | Wi-Fi | 50% |
| Content based selection[3] | Wi-Fi | 16% |
| Transcoding[3] | Wi-Fi | 75% |

## IV. COMPARATIVE ANALYSIS OF VIDEO STREAMING AND ENERGY CONSUMPTION ISSUE

In previous section we discussed on internet protocol stack and the energy consumption issues. From the survey it is found that selection of any technique does not depend on wireless interface or network it depends on the player, the video service provider, video quality, and device .in study it was found that video service use streaming tecInique vary from device to device and also depend on container used . The table 4 below shows the Streaming techniques for popular video streaming services to mobile phones of three major platforms.

*Table.4: Study of Energy Consumption Issue of Video Streaming On Various Parameters*

| | **Android Devices** | **Microsoft Devices** | **Apple Devices** | **Energy Consumption Issue** |
|---|---|---|---|---|
| **Streaming Technique** | On-Off (HTML5&app),Throttling ,Bitrate (Flash) | DASH ,Bitrate,(flash) Fast Caching(app) | DASH (app), Throttling | Energy Consumption in decreasing order DASH <On-Off < Throttling < Bitrate |
| **Quality** | HD 1080p | HD 1080p | HD 1100p | Most of the case Power consumption Increase as we improve the Quality |
| **Container** | 3GPP , MPEG-4, MPEG-2 TS | Silverlight | Flash or the FLV container , MP4 container , M2TS container (for Apple HTTP Live Streaming) | Depend on the Quality like 240p 3gpp video requires less energy than that of an x-flv video ,240p x-flv requires more current than a 720p mp4 |
| **Streaming Services** | Youtube, Daly Motion, Vimeo | YouTube, Daly Motion, Netflix, Vimeo | Youtube, Daly Motion, Amazon Instant ,Netflix | Depend on various characteristics of environment |
| **Video Player** | Flash , HTML5 Native application | Flash , HTML5 Native application | Flash , HTML5 Native application | Native (less energy consumption) Flash player (consume significant amount of energy) HTML5 (Consume more energy) |

Table 5 shows the layer wise energy saving solution provided by different researcher.

*Table.5: The Layer Wise Energy Saving Solution on Different Research Solution*

| **Internet Protocol Stack** | **Solution** | **Energy saving** |
|---|---|---|
| **Physical layer** | Dynamic Modulation Scaling (DMS), Quadrature Amplitude Modulation (QAM), Frequency Shift Keying (FSK) | Dependent on transmission distance |
| **Link layer[LL]** | PSM | 82% |
| | PSM-A | 2% |
| | μPM | 30% |
| **Cross layer** | STPM [20] | 25% |

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| | | |
|---|---|---|
| | PSM- Throttling | 70% |
| | buffer adaptive [20] | **70%** |
| | buffer adaptive [21] | 31-97% |
| | history based prediction mechanism [ [22] | 70% |
| | CoolSpots [23] | 40% |
| **Application layer** | Scalable Video Coding , | 50% |
| | Content based selection | 16% |
| | Transcoding | 75% |

## V. CONCLUSION

In the study we investigated how video streaming effect the power consumption at different layers of the Internet protocol stack, as well as various endpoint of communication path. The researcher gave various solutions to reduce the energy consumption like at physical and link layer solutions in general that is depending on accessing technology. Most of solutions target only multimedia streaming applications. The higher layer solutions, such as traffic scheduling and traffic shaping, can be used. Another way is predict history based traffic and user behaviour, which can be easily implemented in mobile devices. Mobile device vendor or application developer handle the client-centric solution directly. But traffic shaping and scheduling are implemented at the server side or in a proxy. While at Application layer mechanism the energy efficient technique do not make changes in multimedia content but in application layer mechanism apply content adaptation to improve battery life. This will definitely decrease the overhead of sever and network. In study, we also identifies that which feature influence to select the streaming technique Also studied and compare the effect of video qualities, video containers, players, and display types on playback energy consumption on various devices so that selection of streaming technique as per device can be done

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