INDIAN INSTITUTE OF MANAGEMENT KOZHIKODE

Working Paper

IIMK/WPS/469/ITS/2021/08
July 2021

Video and Audio Streaming Over Bluetooth in order to maintain quiet zones

Lija Chandran TV[1]
Mohammed Shahid Abdulla[2]

[1]Independent Consultant, Information Technology and Systems, Email: lijachandran@gmail.com

[2]Associate Professor, Information Systems Area, Indian Institute of Management, Kozhikode, IIMK Campus PO, Kunnamangalam, Kozhikode, Kerala 673 570, India; Email: shahid@iimk.ac.in, Phone Number (+91) 495 – 2809254

Video and Audio Streaming Over Bluetooth in order to maintain quiet zones

Lija Chandran TV
Independent Consultant, Information Technology and Systems
Mohammed Shahid Abdulla
Associate Professor, Information Systems Area, IIM Kozhikode

Abstract

We profile the problem of software applications such as smartphone video players, which carry the effect of noise pollution or disturbance in public places or commuter transport where quiet has now come to be expected, e.g. parks, train carriages, airports, airline flights etc. We propose a partial, software-only solution format to this problem in the absence of users carrying the accessory of earphones or headsets - yet having wearable computing on their person in the form of a digital watch with a suitably-sized screen. Our format also applies to two other use cases, such as the need for video calls when some of the screen-share material (or speaker's video) is confidential to avoid watching in public at at maximum resolution, or hearing audibly, from the existing hosting device.

1. Problem Statement

Smartphones are a dominant mobile communication gadget, and have also become the favoured digital device for a large section of our population for entertainment: i.e. to watch videos and listen to music. The boom in several audio and video streaming platforms (OTT) has made access to such entertainment formats very easy in a smartphone, aided by inexpensive internet access plans via smartphone. In addition, a large proportion of the message content being exchanged using smartphones is also in the video format, colloquially referred to in India as 'forwards'. A recent report[1] on mobile broadband performance says that Indians spend approximately 5 hours *per day* on smartphones and that short videos are the fastest growing content segment.

Yet, there is also a level of civic nuisance that accrues when such content is being consumed by users in public places without the appropriate peripherals, viz. a earphones' set. This may be associated with the population profile of India and its rapidly urbanising semi-skilled population, where smartphone engagement is in the large part restricted to video 'forwards' on messaging apps or video content from OTT firms. According to a newspaper report[2], BMTC (Bangalore Metropolitan Transport Corporation) has issued a notice to take action against people playing loud music in buses.

It is easy to see that this practice is uncommon even in other parts of the globe. A newspaper in Ireland conducted a poll[3] to understand whether “it is acceptable to watch videos on public transport without headphones” - with nearly 90% responding “No”.

Further, reports suggest many cities in China including Shanghai[4], Kunming[5], Beijing and Lanzhou have brought in regulations to ban public transport users from listening to loud music, watching noisy videos or talking loudly on phones. It is an existing airline policy in the US that all audio tracks playing from personal electronic devices will require use of headphones[6]. However, it is also the case that merely speaking on smartphones can also reduce the level of quiet in a closely-packed public place, yet such a facility is permitted under the assumption that it will last only for a minimal amount of time and may also be an essential exchange of information.

A columnist working for the technology press in California, USA, also complained in his outlet about an episode[7] in a restaurant where he was disturbed by people playing loud videos on their smartphones (without headphones). These reports are indicators that smartphone users are not carrying their headphones everywhere. It is also the case that users who do wear bluetooth enabled earphones or earbuds at all times have a level of social difficulty - such cases among Apple Airpod users being referred to as the ‘AirPod barrier’[8]. While earphones may also be treated as wearables, the popular press has also carried a variety of health concerns related to always-on earphones[9]. If not treated as a wearable, then fail-proof storage of this accessory may not be engaged in by a large number of users, who do not however forget to carry the smartphone as it is linked to essential information, payment mechanisms, ability to browse the internet etc.

In this paper we propose a software-only solution for playing video in public places, by using a smartphone-smartwatch combination as an alternative to carrying the headset device. Our solution would also work for media player - enabled gadgets like Laptop and Tablet. It is also of utility in specific situations such as confidential video meetings that require to be conducted when the active participant is in a public place or inside a closely-packed mode of transport such as buses, trains or flights. We explain the background technologies that we require for our solution in Section 2. We describe the 3 use cases which are fairly common and the partial, software-only solutions that are geared towards these use cases in Section 3. We close with a description of some future directions in Section 4. Solutions are called ‘partial’ since they are not a substitute for the ideal outcome, i.e. they do not deliver higher screen size resolution or maximum audio quality. These results would be available only if the smartphone-owner is in a location without risk of disturbance to others, or, alternatively, if an earphone or headset accessory is available.

2. Harnessing Bluetooth

Bluetooth wireless technology[10] enables wireless data exchange between devices in a close range upto 10 meters. Connectivity across different portable devices on different platforms can be established using Bluetooth wireless technology. For eg. a Windows OS laptop computer and an Android OS mobile phone can be connected for data transfer, a laptop and a Bluetooth enabled speaker or a Bluetooth headset can be connected wirelessly (this is common practice in many work or conference-call situations).

To signify the importance of Bluetooth in enterprise environments: according to an article[11], Bluetooth enabled gadgets like keyboard, mouse and headset can improve productivity while you are away from the office desktop and have to work on mobile devices like laptop, tablet or smartphones. A report[12] says that upto a 43% boost in productivity can be achieved at work with the help of wireless headphones. A recent article[13] by an industrial communications consultant says that Bluetooth enabled Mesh Intercom solutions can boost productivity, collaboration and safety in industrial work environments generally as well as due to current adherence to Covid-19 protocols.

In addition, at the consumer end of the spectrum, a smartphone and an associated smartwatch - a type of device which falls in rubric ‘wearable’ - can also be connected for data transfer. This is mostly to log the data collected by the watch about the wearer’s sleep, health and fitness variables into the smartwatch’s mirror app present in the phone. Wearables such as a smartwatch present the advantage that they do not have to, per se, be carried unlike a laptop’s BT speaker set or headset. An indicator of the typical bluetooth-enabled device, acting in an ecosystem around the central device, is in the below figure. Note that the arrows indicating useful data transfer can be bidirectional.

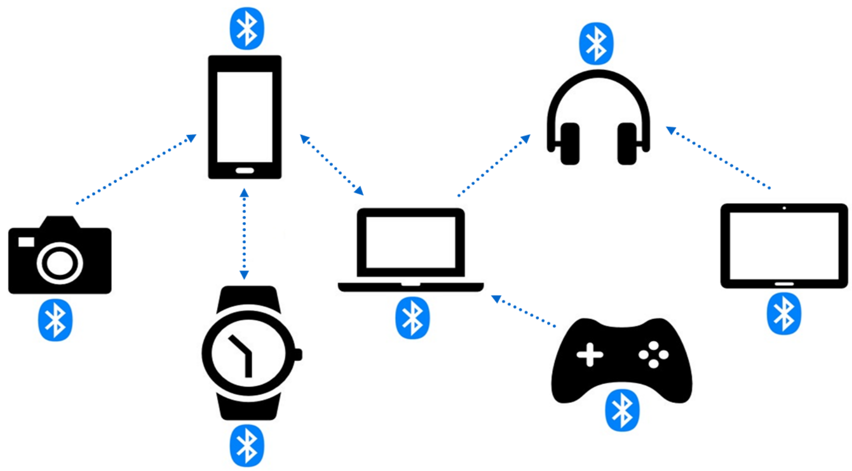

Figure: 1

2.1. Bluetooth Profiles

There are different Bluetooth profiles[14], which are specifications defined according to the functionality expected from the devices using Bluetooth wireless technology. Some of the common profiles which are used in Bluetooth devices are listed below:

- File Transfer Profile (FTP) - used to transfer objects (files, folders) in a filesystem to another system.
- Hands-Free Profile (HFP) - used for communication between mobile phone and car hands-free kits
- Headset Profile (HSP) - used to connect mobile phones or laptops with the bluetooth headset, earphones or earpods.
- Message Access Profile (MAP) - used to exchange text messages between devices.

To highlight a novel application of Bluetooth, Hongkong's protest groups use a message-passing app viz. Bridgefy (available on both the major smartphone OS) which is built entirely in Bluetooth, and which avoids the mobile service providers' network. Bluetooth has a formal MESH profile, though Android and iOS devices don't appear to support the profile proper, but permit the apps to be used on their smartphones.

2.2. Advanced Audio Distribution Profile

In addition, the Advanced Audio Distribution Profile (A2DP)[15] in Bluetooth defines parameters and procedures for streaming multimedia audio from one device to another over the wireless Bluetooth connection. This is the profile used when the audio is streamed from a mobile phone to a Bluetooth enabled headset or speaker.

Two different roles are defined for the devices which implement the A2DP profile:

- Source (SRC) - the device which is the source of digital audio stream
- Sink (SNK) - the device which receives the digital audio stream

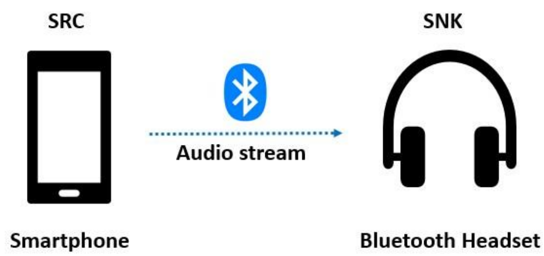

Figure: 2

2.3. Video Distribution Profile

Similarly, the Video Distribution Profile (VDP)[16] describes the protocols and procedures for streaming video content from one Bluetooth enabled device to the other. Note that the data rate required for video stream is 3-4x higher, depending on the compression algorithm used, compared to audio. Similar to A2DP profile, the device which implements VDP has to define the following roles:

- Source (SRC) - the device which is the source of digital video stream
- Sink (SNK) - the device which receives the digital video stream

In our research, we found two devices: a Bluetooth Surveillance Camera, and a Bluetooth webcam, but both these devices are no longer in production. Besides, we could not fully verify if VDP was being used in these devices.

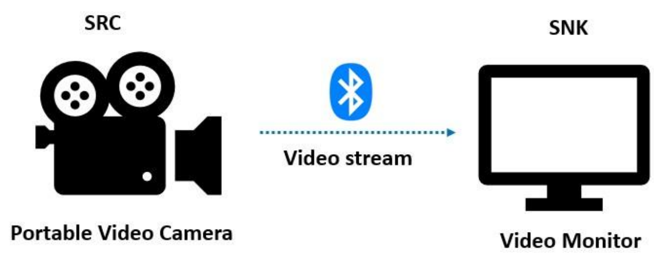

Figure: 3

2.4. Data Transfer Throughput

Different versions of Bluetooth come with improved sets of specifications to support the latest technologies and requirements. According to the data from Bluetooth's Blog[17], the data transfer throughput of recent versions of Bluetooth are as follows. There have also been experiments[18] testing the claimed theoretical bandwidth against throughput similar to the one reported here.

Bluetooth Version	Year of rollout	Bandwidth (Mb/s)	Throughput (Mb/s)
4.0/4.1	2010/2013	1	0.305
4.2	2014	1	0.803
5.0	2016	2	1.4

Table: 1

3. Video Streaming

The solution proposed in this paper involves the streaming of video to a screen-enabled wearable device, typically a smartwatch, using Bluetooth wireless technology. From the initial versions of Bluetooth, different kinds of experiments were done on video streaming over the Bluetooth wireless technology. There are research articles which demonstrate that streaming video over Bluetooth is possible with even initial versions of Bluetooth; streaming to a Linux OS -based desktop from a Nokia mobile phone[19] and a real time video stream (176x144 pixel, 15 frames per second) was transmitted from the mobile phone's video camera to the desktop workstation via Bluetooth at an average data rate of 64 kbits/s. As expected, the quality of the video degraded when the distance between the devices increased.

Another experiment on streaming video using MPEG-4 wireless video codec[18] found that the higher compression rate of MPEG-4 resulted in a reasonably good video quality despite the bandwidth limitation of Bluetooth.

We can conduct a calculation to examine the feasibility of streaming video over Bluetooth. The bandwidth required to stream a 240p (426x240 pixel resolution with aspect ratio 16:9) video with true color of 24 bit per pixel and 30 frames per second, without using any compression techniques is:

$$426 \times 240 \times 30 \times 3 = 70.2 \text{ Mb/s}$$

In the above, we have considered the resolution to be an upper-bound for the pixel resolution available in smartwatches on sale presently (refer Table 2 below). Further, with the support of various digital compression and decompression codecs on both the smartphone and the smartwatch (or any other sink), the bandwidth requirement for streaming a video can be reduced to a great extent. Below is a tentative formula to calculate bitrate from a book-length resource[20] which explains H.264 encoding:

[image width in pixels] x [image height in pixels] x [framerate in frames/second] x [motion rank (an indicator of amount of motion in the video)] x 0.07 = [desired bitrate]

If we use the commonly-employed H.264 codec to stream a 240p video, the bitrate will calculate to the following using the above-mentioned formula:

$$426 \times 240 \times 30 \times 2 \times 0.07 = 0.41 \text{ Mb/s}$$

Youtube being one of the major video streaming platforms, we obtained the bitrate range mentioned in Youtube's live video streaming recommendation[21] , an article about a test conducted on Youtube’s data usage[22]. The average bitrate ranges are reproduced below:

Video Quality	Resolution (pixels)	Frame Rate (FPS)	Bitrate (average)	Data used per minute	Data used per 60 minutes
144p	256x144	30	80-100 Kbps	0.5-1.5 MB	30-90 MB
240p	426x240	30	300-700 Kbps	3-4.5 MB	180-250 MB
360p	640x360	30	400-1,000 Kbps	5-7.5 MB	300-450 MB

Table: 2

The above listed bitrates and the result of calculations indicate that the 144p, 240p and 360p videos can all be easily streamed over Bluetooth version 5.0, the practical throughput of Bluetooth 5.0 being 1.4Mbps (Section 2.4 above). However, such streaming - without compression - would not be feasible in any of the earlier versions of Bluetooth. Smartphones with Bluetooth 5.0 support were launched from 2017 onwards, though most brands started manufacturing Bluetooth 5.0 smartphones only from 2018[23]. Further, many smartwatches also support the Bluetooth 5.0 version (refer to Table 3 in section 6.1).

A research paper[24] on live video streaming over Bluetooth in Android wearables has already demonstrated streaming video from a smartwatch to an Android smartphone: the reverse direction of what we desire, as also for a different use-case. The assumption was also of a source being a camera-enabled smartwatch, a situation that is likely to be rare since camera-enabled smartwatches are few in number. Whilst there are smartwatches with a camera as a peripheral, these do not appear to be from top brands or enjoy high sales. In India, a popular smartwatch's variant is available and the description calls the device a 'memographer' - to capture a large number of low-resolution pictures rather than a few high-resolution pictures. Such a niche application does not suggest the device will achieve widespread use. In other experiments, video streaming was done with the help of the Android Bluetooth Socket APIs[25] and the devices used for the experiment had an in-built hardware codec, even within a profile as compact as a smartwatch, to perform image compression before streaming.

Another paper[26] claims to have developed a framework to enable task delegation between smartwatch and smartphone using Bluetooth. The framework describes a scenario where the video being played on the smartphone will be automatically transferred to the smartphone in a low resolution format, when an incoming call requires to be answered on the phone. The authors have some demonstrations in the paper showcasing the task delegations using the apps they designed. Shifting the video to a smartwatch in order to receive an incoming phone call does not solve the problem of the video's audio-track becoming muted, though it is true that the framework can be expanded to handle such a case. Note also that our solution format does not require task migration, which may have additional overheads. We only require audio or video streaming.

However, it is certainly feasible to adapt such a task-migration framework to the use-cases that we discuss, and we record this in our conclusions. We cover our solution's features for the primary use-case's requirement, in the next section.

4. Playing of audio via earpiece of smartphone

For our proposed solution, audio requires to be played via the earpiece of the phone. The popular messaging app Whatsapp currently uses this method in conjunction with proximity sensors to play audio messages, when the phone is raised vertically and brought close to the user's ear. There are apps like *Earpiece* and *Stealth Audio Player* on the Android platform which also stream the audio to be played through the earpiece of the phone. Note the distinction here: while audio would normally play through the smartphone's speakers, these 3 cases result in audio being streamed through the phone's earpiece, which would also result in lower fidelity for the audio experience.

The crowdsourced developer query thread[27], is populated with what appear to be enthusiasts or developers of enterprise or niche apps, discussing solutions for routing of audio to earpiece in Android mobile handsets, with activity even in the current year. It is worthy of note that many of the use-cases for audio diversion to the earpiece are by default - indicating that it is the enthusiasts' first preference. The appropriate media player used on the phone is then being re-configured by these enthusiasts to present an option where audio is diverted to the phone's speaker, if required. A modification similar to this is what we require for one feature described in Section 5. Android SDK library[28] functions can be used to route the audio output to the earpiece[29].

5. Proposed solution format

Our proposed solution presumes that all possible source-sink devices are enabled with Bluetooth version 5.0 or higher, connected and paired with each other, and have media players installed. The existing media players on smartphone or laptop computer will require to have updated versions to support the two options that we propose:

- Stream audio to a Bluetooth paired device and
- Stream video to a Bluetooth paired device

For example, the media player on the smartphone should have an option to stream the video to the media player in the smartwatch. Also, as mentioned in Section 4, the audio-track (soundtrack) of the video is routed to the earpiece of the smartphone while the video-track is streamed to the Bluetooth paired device, in this case the smartwatch. Note here that the incentive to companies with media player or video conference application products is the reputation for having enabled quieter public or office places, besides being a new feature that would attract attention of new buyers for a period of time. This may also be perceived by the buying public to be correlated with the company's sustainability and environment-friendly approach or brand image.

For another use case that we describe later, an enhancement required in smartphones would be to act as the Bluetooth audio receiver (sink), i.e. smartphones should be able to act as an A2DP SNK device as mentioned in section 2.2. Currently smartphones are configured to act as A2DP SRC devices and the changes are recommended to be made at the operating system level[30] to configure smartphones as A2DP SNK device. Some brands appear to have taken the lead in this regard; a recent update in a popular operating system[31] enables the devices with this specific OS update to use it as an A2DP SNK.

There are two options to enable video streaming among the devices, one is to configure these devices as VDP SRC and SNK (refer section 2.3), which would require configuration changes in the operating system. Currently the top operating systems have not yet started supporting Bluetooth's VDP profile[32][33][34][35]. The other option available is to use the APIs provided by the respective operating systems and implement the same in the media players to establish the Bluetooth socket connection and then stream video (in the similar fashion as mentioned in research paper[24]).

6. Usecase 1: Video Streaming to Smartwatch from Smartphone

Here we will be discussing a scenario where a person travelling in public transport wants to watch a video on their smartphone but does not have an earphone presently, however a wearable in the form of a smartwatch is available, and it supports playing of multimedia. Streaming video to smartwatches can be done as per the bit rates and resolutions mentioned in section 3, besides these range of display resolutions are also supported by smartwatches in section 6.1, with the additional requirement that hardware video codec support also exists (a list of smartwatches with these is in section 6.2). The proposed solution can be used to watch video without disturbing the people around, by:

- Listening to the audio using the earpiece of the phone and
- Streaming the video component to the smartwatch

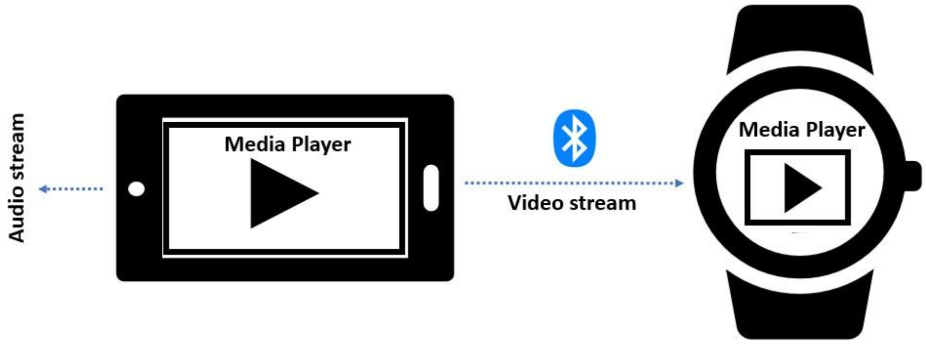

Figure: 4

6.1. Display resolutions supported by smartwatches

The video that will play in the smartwatch will be a thumbnail version of the actual video. However, it is expected this will suffice since many video players on the mobile OS - most notably YouTube player - already have thumbnail videos that play in the background. Such a video plays in a corner of the smartphone's available touchscreen area, whilst the user may attend to other tasks on the phone. Many users are by now familiar with thumbnail videos, and find these to be fairly satisfactory for resolution, esp. for cursory watching of news clips or short-video forwards on messaging apps.

The standard aspect ratio of Youtube player is 16:9 and the different resolutions supported by Youtube player on Desktop and Android phones are listed below:

- 1080p : 1920x1080
- 720p : 1280x720
- 480p : 854x480
- 360p : 640x360
- 240p : 426x240
- 144p : 256x144

Table 3 below has a list of smartwatches from several brands and the corresponding display, resolution and operating system. Many suit the 240p thumbnail, others are 144p.

Brand and Model	Bluetooth Version	Size "(Main Display)	Resolution (Main Display)	OS	Processor
Samsung Galaxy Watch Active2	5.0	1.4"	360x360	Tizen	Exynos 9110
Samsung Galaxy Watch 3	5.0	1.4"	360x360	Tizen	Exynos 9110
Fossil Garrett HR	4.2	1.25”	416x416	Wear OS	Snapdragon 3100
Fossil Q The Carlyle HR	4.2	1.25”	416x416	Wear OS	Snapdragon 3100
Apple Watch Series 6	5.0	1.73" and 1.57"	368x448 and 324x394	watchOS	Apple S6
Apple Watch Series SE	5.0	1.73" and 1.57"	368x448 and 324x394	watchOS	Apple S5
Mobvoi Ticwatch Pro 2020	4.2	1.39”	400x400	Wear OS	Snapdragon 2100
Mobvoi Ticwatch Pro 3 GPS	5.0	1.4”	454x454	Wear OS	Snapdragon 4100
Mobvoi Ticwatch S2	4.1	1.39”	400x400	Wear OS	Snapdragon 2100
Motorola Moto 360	4.2	1.2”	390x390	Wear OS	Snapdragon 3100

Table: 3

Note also that thumbnail video with a nonstandard aspect ratio 16:9 (or videos that have been shot in nonstandard aspect ratio) may also be accommodated, in many cases, in the above smartwatch models with use of codecs that adjust to different resolution ratios.

6.2. Hardware enabled video encoding and decoding

Most of the smartwatches have a video codec in-built with the processor. Following are the commonly used processors[36][37] used in smartwatches from many leading brands, and all of these processors have in-built video codec support. In Table 3 above, 7 out of the 10 watches that we have listed use these processors and their associated computing platform, i.e. chipset.

	Exynos 7 Dual (7270)	Exynos 9110	Snapdragon 400	Snapdragon 2100	Snapdragon 3100
Clock Speed	1.0GHz	1.1GHz	1.7 GHz	1.2 GHz	1.2 GHz
Video/ Display	HD 30fps	720p 30fps	1920x1200	640x480 at 60fps	640x480 at 60fps
Hardware Codec	HEVC, VP8	HEVC(H.265), H.264 and VP8	H.263, H.264, VP8	Adreno 304 GPU: H.264, H.265/HEVC, VC-1	Adreno 304 GPU: H.264, H.265/HEVC, VC-1

Table: 4

7. Usecase 2: Audio streaming from Laptop to Smartphone

In this scenario, if a person wants to watch a video or needs to attend a video conference call on their laptop or tablet in a public place, they can make use of our proposed solution to:

- Play the video on the laptop/tablet and stream the audio to the smartphone over Bluetooth
- Listen to the audio using the earpiece of the phone

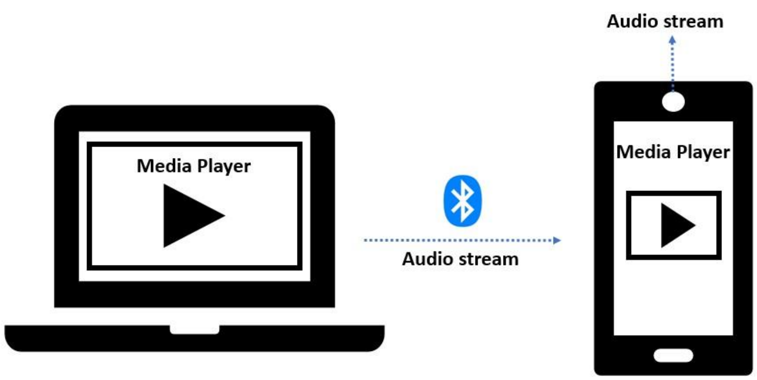

Figure: 5

In this particular case, note that video conferences are implemented using applications like Zoom, Webex or browsers (Google Meet). Currently these applications have the option to select the audio/video output and input devices among the devices connected to the laptop, including the Bluetooth headsets. In our solution, the paired smartphone will be advertised as A2DP SNK device, thus it will be listed as an audio output device in the laptop. It can therefore be used as audio output for updated versions of applications. This feature will be useful in the use case mentioned in the upcoming section 8 also.

There exist apps like *SoundWire*, *AudioRelay*, *PocketSpeaker* and *wireless speaker* for android which enable streaming of audio from Linux or Windows laptop to android smartphone and use it as a remote speaker or wireless headphone. But these apps use audio mirroring or audio casting over WiFi to stream the audio directly to your android device. Further, these apps will play the audio through the speaker of the phone.

8. Use case 3: Video streaming from Laptop to Smartwatch

This use case focuses on a scenario where a need appears, in the middle of a video conference call, to discuss confidential visual exhibits (e.g. a soon-to-be-released product or design) while in a public place. For example, if an employee of an organization is on an official trip and they are in a waiting room of a railway station or airport, with the need to watch a screen-shared video about an upcoming product. Alternatively, there are slides being screen-shared in the meeting that the laptop user is attending, however a number of these slides are confidential because they contain parameters or negotiation text. At that point in the video call, the video can be streamed to the smartwatch by the user for a suitable length of time with the help of our proposed solution. Thus people around him/her wouldn't be able to take a peek into the confidential data on the comparatively large screen of the laptop.

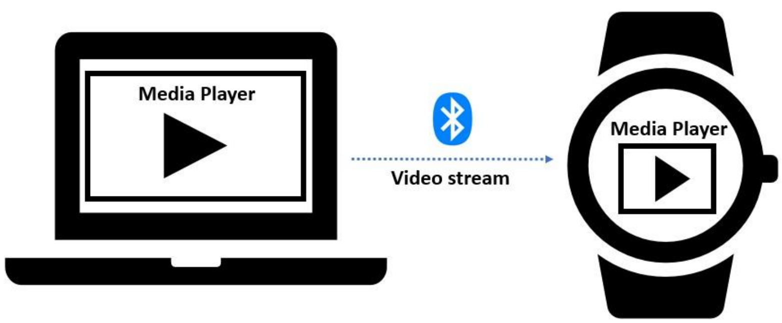

Figure: 6

It is important to note that the employee could already be carrying a headset accessory, in anticipation of needing to attend such a meeting while on travel. However, even if this is not true, the audio from the laptop can also be streamed to the smartphone using our proposed solution (refer to Use Case 2 above).

Conclusion and Future Directions

There are many portable digital-ready gadgets available in the market which aid in watching and listening to multimedia. Though earphones/headset are among these gadgets, people may not carry them in all places. Given the emphasis on health and fitness in urban living, as well as the gradual replacement of analog wristwatches, a smartwatch is a wearable whose availability in settings is high. A solution to both watching and listening to the multimedia content, without using earphones/headphones, is thus required under such assumptions. The solution format proposed by us can stream the video in a multimedia content into an alternate gadget available with the people like a smartwatch and further play the audio via the earpiece of the phone. This reduces the noise in public places which are classified as silent-zones like airports, modes of transport, or similar locations. A future direction for our solution format is to be able to adapt the task transfer framework between devices, with attention to the missing audio streaming component, to solve for these use-cases.

References

[1] Nokia. (2021, Feb). *India Mobile Broadband Index 2021*. https://www.nokia.com/sites/default/files/2021-02/Nokia-MBiT-2021.pdf

[2] Times of India. (2019, Sep 21). *Bengaluru: No loud music in buses*. https://timesofindia.indiatimes.com/city/bengaluru/bengaluru-no-loud-music-in-buses/articleshow/71228845.cms

[3] MacNamee, G. (2019, Jan 23). *Poll: Is it acceptable to watch videos on public transport without headphones?* TheJournal.ie. https://www.thejournal.ie/poll-headphones-4454504-Jan2019/

[4] The Straits Times. (2020, Dec 2). *Shanghai subways ban use of speakers on mobile phones and digital devices.* https://www.straitstimes.com/asia/east-asia/shanghai-subways-ban-use-of-speakers-on-mobile-phones-and-digital-devices

[5] Zhang, T. (2019, Aug 28). *This Chinese City Wants to Ban Loud Noises on the Metro*. JY International Cultural Communications Group magazines. https://www.thatsmags.com/china/post/29240/chinese-city-to-battle-against-metro-passenger-noise

[6] Hester, E. (2019, Aug 1). *Everyone has to wear headphones on airplanes. Yes, even your kid*. Los Angeles Times.

https://www.latimes.com/travel/story/2019-07-30/blasting-sound-on-a-plane-is-rude-use-headphones

[7] Matyszczyk, C. (2019, Jan 13). *How three rude iPhone users ruined an evening.* ZDNet. https://www.zdnet.com/article/how-three-rude-iphone-users-ruined-an-evening/

[8] Kantrowitz, A. (2019, Apr 17). *People Wearing AirPods Are Making Things Awkward For Everyone Else*. Buzzfeed News. https://www.buzzfeednews.com/article/alexkantrowitz/people-wearing-airpods-are-making-things-awkward-for

[9] Siddiqui, N. A. (2019, May 25). *Here's how prolonged earphone use can infect or damage your ears*. Business Standard. https://www.business-standard.com/article/health/here-s-how-prolonged-earphone-use-can-infect-or-damage-your-ears-119052500964_1.html

[10] Haartsen, J., *et al.*(1998, Oct). *Bluetooth: Vision, Goals, and Architecture.* ACM SIGMOBILE Mobile Computing and Communications Review, 2, 38-45. http://dx.doi.org/10.1145/1321400.1321402

[11] Shoer, M. J. (2016, July 26). *3 Bluetooth gadgets for enhanced productivity on mobile devices*. Internet & Telephone. https://www.itllc.net/it-support-ma/tip-of-the-week-3-bluetooth-gadgets-for-enhanced-productivity-on-mobile-devices/

[12] Auld, A. (2018, April 9). *43% boost in productivity with a wireless headset at work*. Teleco. https://teleco.ca/43-boost-in-productivity-with-a-wireless-headset-at-work/

[13] Clarke, C. (2021, March 19). *Advances in worksite connectivity boosts productivity, collaboration and safety -- Occupational health & safety*. Occupational Health & Safety. https://ohsonline.com/articles/2021/03/19/advances-in-worksite-connectivity.aspx

[14] Wikipedia. (accessed in Jul, 2021). *List of Bluetooth profiles*. https://en.wikipedia.org/wiki/List_of_Bluetooth_profiles

[15] Bluetooth. (2019, Jan 21). *Advanced Audio Distribution*. https://www.bluetooth.com/specifications/specs/advanced-audi%e2%80%8b%e2%80%8bo-distribution-profile-1-3-2/

[16] Bluetooth. (2012, Jul 24). *Video Distribution Profile*. https://www.bluetooth.com/specifications/specs/video-distribution-profile-1-1/

[17] Ren, K. (2017, Feb 20). *Higher Speed How Fast Can It Be?* https://www.bluetooth.com/blog/exploring-bluetooth-5-how-fast-can-it-be/

[18] Chia, C., & M, S. B. (2002, Dec). *MPEG-4 Video Transmission over Bluetooth Links*. http://dx.doi.org/10.1109/ICPWC.2002.1177293
[19] Catania, D. (2008, Jan). Video Streaming over Bluetooth. https://core.ac.uk/download/pdf/132620298.pdf
[20] Amerasinghe, K. (2010). *H.264 For The Rest Of Us*. https://issuu.com/konu/docs/h264_primer
[21] Google. (accessed in Jul, 2021). *Choose live encoder settings, bitrates, and resolutions*. https://support.google.com/youtube/answer/2853702
[22] Hindy, J. (2019, Jun 30). *How much data does YouTube actually use?* https://www.androidauthority.com/how-much-data-does-youtube-use-964560/
[23] Face of IT Reviews.(2018, June 30). *Top Android smart phones with Bluetooth 5.0 low power BLE support*. https://www.faceofit.com/reviews/top-android-smart-phones-with-bluetooth-5-0-low-power-ble-support/
[24] Saminath V. (2015, May). *Live Video Streaming in Android Wearable Devices.* International Journal of Scientific and Research Publications, 5(5). http://www.ijsrp.org/research-paper-0515.php?rp=P414060
[25] Android. (accessed in Jul, 2021). *BluetoothSocket*. https://developer.android.com/reference/android/bluetooth/BluetoothSocket
[26] Xu, Y., Wang, L., Xu, Y. *et al.* (2019, Aug 14). *Cross-device task interaction framework between the smart watch and the smart phone*. Personal and Ubiquitous Computing. https://link.springer.com/article/10.1007/s00779-019-01280-7
[27] Stack Overflow.(accessed in Jul, 2021). *Android - Play audio from earpiece*. https://stackoverflow.com/questions/13960313/android-play-audio-from-earpiece
[28] Android. (accessed in Jul, 2021). *AudioManager*. https://developer.android.com/reference/android/media/AudioManager?hl=pt-br#ROUTE_EARPIECE
[29] Stack Overflow. (accessed in Jul, 2021). *Android - Getting audio to play through earpiece*. https://stackoverflow.com/questions/2119060/android-getting-audio-to-play-through-earpiece
[30] Stack Overflow. (accessed in Jul, 2021). *Receive audio via Bluetooth in Android*. https://stackoverflow.com/questions/15557933/receive-audio-via-bluetooth-in-android
[31] Parmar, M. (2020, Jun 8). *Windows 10 gets Bluetooth A2DP sink feature: Here's how to use it*.

https://www.windowslatest.com/2020/06/08/enable-and-use-windows-10-bluetooth-a2dp-sink/
[32] Apple. (2019, Sep 19). *Bluetooth profiles that iOS and iPadOS support*. https://support.apple.com/en-us/HT204387
[33] Microsoft. (accessed in Jul, 2021). *Supported Bluetooth profiles*. https://support.microsoft.com/en-us/windows/supported-bluetooth-profiles-8900e50f-318e-4283-2beb-c8325bfc9515
[34] Android. (2020, Sep 01). *Bluetooth Services*. https://source.android.com/devices/bluetooth/services#bluetooth-profiles
[35] ThinkPenguin. (2019, Sep). *Bluetooth Profiles Supported Under GNU/Linux*. https://www.thinkpenguin.com/gnu-linux/bluetooth-profiles-supported-under-gnulinux
[36] Samsung. (accessed in Jul, 2021). *Show all processors*. https://www.samsung.com/semiconductor/minisite/exynos/products/all-processors/
[37] Wikipedia. (accessed Jul, 2021). *List of Wear OS devices*. https://en.wikipedia.org/wiki/List_of_Wear_OS_devices

Research Office

Indian Institute of Management Kozhikode

IIMK Campus P. O.,

Kozhikode, Kerala, India,

PIN - 673 570

Phone: +91-495-2809237/ 238

Email: research@iimk.ac.in

Web: https://iimk.ac.in/faculty/publicationmenu.php