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A Study on Applications of Wi-Vi Technology

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Abstract- A popular technology called Wi-Fi is nothing but the information carrier between transmitter and receiver. Through this paper, we show that Wi-Fi can also extend our senses, enabling us to see moving objects through walls and behind closed doors. So can we use Wi-Fi signals to identify people in a closed room with their relative location? Yes, we can achieve the identification of objects in closed rooms through a technology called Wi-Vi. One can also identify simple gestures and combine a sequence of gestures behind the wall to communicate messages. This introduces two main innovations. Initially, it uses MIMO interference nulling to eliminate the static object reflections and target the focus on moving objects. Next, it shows how one can track a human by treating the motion of a human body as an antenna array and tracking the resulting RF beam. It helps in various applications which are given in the papers that helps the human to save life in critical conditions.

Keywords: MIMO

I. INTRODUCTION

First, the creator of Wi-Vi is Dina katabi and his graduate student Fadel Adib. The expansion of Wi-Vi is a wireless vision. It works in two modes first is, find moving objects behind the wall and second is a gesture-based interface. As said above, we can find moving objects behind the wall, how many persons are in a closed room and many more. And also we can do a gesture-based interface with the Wi-Vi device. The antenna used in the Wi-Vi device is three, two for transmitting and one for receiving. And it will not be used in the separate device but it will use the Wi-Fi device hardware, i.e. the technology developed based on Wi-Fi device.

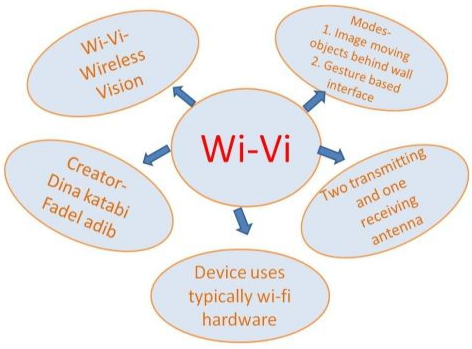


Fig 1: Overview

The researcher has long attempted to build a device capable of seeing people through the wall. However, few of the previous effort to develop such a system has involved expensive and bulky radar technology that uses a part of the electromagnetic spectrum only available to the military. Now a system being developed by MIT researchers could give all of us ability to spot people in the different room using low-cost Wi-Fi technology. The system called Wi-Vi is based on a concept similar to radar and sonar imaging. But when compared with radar and sonar. Wi-Vi transmits a low power Wi-Fi signals and also it uses its reflection to track moving human movements. It can do so even if the humans are in a closed room or hiding behind a wall. Wi-Fi is behind the wall as indicated by that arrow. The blue window at the bottom shows the output of Wi-Vi. The Room is Initially empty this is why the signal is zero. A person enters a room, as he moves away, the device shows a negative signal. when he moves toward the device, it shows a positive signal. When he stops it outputs only the Zero. Meaning there is no motion, even though he performs a minor movement with few footsteps the Wi-Vi get to register the motion of the person and it sends to process the output data.

II. EXISTING SYSTEM

1. Through Wall Radar

Researchers have the aim to build a device capable of seeing people through walls. However, previous efforts to develop such a system have involved the use of expensive and bulky radar technology that uses a part of the

electromagnetic spectrum only available to the military. They mainly focus on modeling and simulations. Recently few applications have been tested with humans in moving position. Earlier systems helped in to eliminate the flash effect by isolating the reflected signal of the wall from the reflected signals of the objects behind the wall. This isolation can be achieved in the time domain by using very short pulses (about 1 ns) due to which delay had been developed between the arrival time of reflected signal off the wall and reflected a signal off the moving objects behind the wall. Isolation can also be achieved in the frequency domain through linear frequency chirp. In this, reflections from objects at different position arrive with different quality. By doing analog filtering of signal qualities correspond to the wall may lead to removing flash effects. All these techniques need ultra-wide bands (UWB) of the order of 2GHz.And another through-wall imaging product was based on radar principle which also needs (UWB) and applicable for military purpose.

But the Wi-Vi system has different features as it requires law bandwidth, and operates in the same range as Wi-Fi. Wi-Vi overcomes the requirement for the UWB by using MIMO nulling to remove the flash effect. These systems work as, they separate reflections off the wall from reflections from the objects behind the wall based on their arrival time, and hence arises the need to identify delay (i.e. nanosecond) to filter the flash effect.

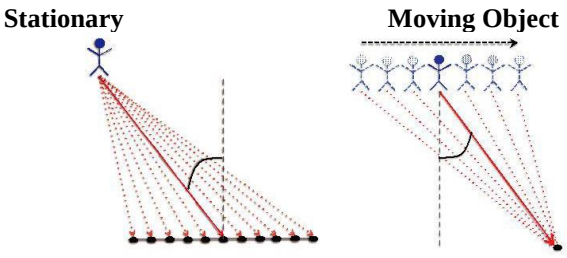
Wi-Vi uses two antennas at the transmitter side and a receiving antenna. The two antennas transmit almost identical signals, except the second antenna signal is an inverse of first, resulting in its inference.

2.Gesture-Based Interfaces

Currently, there are commercial gesture recognition systems such as the ninteudowii, Xbox Kinect etc., which can be used to identify a variety of gesture. There is also such system that is capable of identifying human gestures by employing cameras or placing the sensor on the human body. Recent work has also using narrowband signals in the range of 2.4 GHz to identify human activities in the line of sight by using Micro-Doppler signatures [3]. Wi-Vi, however, presents the first gesture-based interface which works in nonline of sight scenarios & even through the wall and hence human is not required carrying a wireless device or wearing a sensor on their body.

3. Infrared and Thermal Imaging

Infrared and thermal imaging based systems extend the human vision beyond the visible electromagnetic range and allowing us to detect objects in presence of smoke & darkness. This system is operated by capturing infrared or thermal energy reflected from the first obstacle in the line of sight of their sensors. But this technology does not allow us to see through walls due to having a short wavelength (few μm to sub-mm), whereas the Wi-Vi system having a wavelength in the range of 12.5cm [5].



a. Antenna Array b. ISAR

Fig 2: A Moving Object as an Antenna Array. In (a), an antenna array is able to locate an object by steering its beam spatially. In (b), the moving object itself emulates an antenna array; hence, it acts as an inverse synthetic aperture.

4.Eliminating the Flash Effect

In any see-through wall system, the flash (i.e. signal reflected from the wall) is much stronger than any signal reflected from the objects behind the wall. This is due to the electromagnetic signals produce significant attenuation when penetrating on dense obstacles. Table 1 shows an example of a one-way attenuation experienced by Wi-Fi signals.

Table 1: One-Way RF Attenuation in Common Building Materials at 2.4GHz

Building Materials	2.4 GHz
Glass	3 dB
Solid Wood Door 1.75 inches	6 dB
Interior Hollow Wall 6 inches	9 dB
Concrete Wall 18 inches	18 dB
Reinforced Concrete	40 dB

For example, when the signal is traveled through glass or concrete wall, the Wi-Fi signal power is reduced by 3dB and 18dB respectively. The problem is caused by two factors.

1. The actual reflected signal is significantly weaker than the wall which is much larger than the objects of interest and has a higher reflection coefficient as well as a cross-section of the object [5].
2. The direct signal from transmitting to the receiver antenna, which is significantly larger than the reflections of actual objects.

Wi-Vi uses MIMO nulling to overcome the above two problems, hence increasing its focus on the reflections of the actual object.

5.Nulling to Remove Flash

The MIMO technique can be used to eliminate the flash effect and direct signal from transmitting to the receive

antenna, which enables Wi-Vi to capture the reflections from the actual object with minimal interference. Wi-Vi's nulling procedure can be broadly divided into three phases, i.e. initial nulling, power boosting and iterative nulling.

Initial Nulling: In the initial nulling process, Wi-Vi uses MIMO system to pre-code transmission such that the signal received at a particular antenna is canceled. This technique can be used to remove flash effect and the direct signal from the transmit to receive antenna, which enables Wi-Vi to capture the reflections from a target object with minimal interference. Wi-Vi has two transmits antennas and one receive antenna.

1. The device transmits a known preamble x only on its first transmit antenna. This preamble is received at the receive antenna as y= h1x, where h1 is the channel between the first transmit antenna and the receive antenna. And the receiver uses the above-obtained signal in order to compute an estimate of the channel h1.

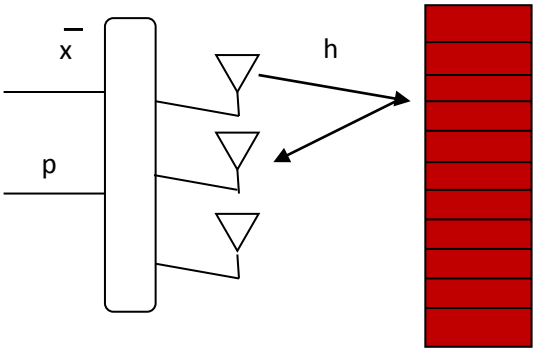


Fig 3: Signal Transmission on First Antenna

2. Second, the device transmits the same preamble x, this time only on its second antenna, and uses the received signal to estimate channel h2 between the second transmit antenna and the receive antenna.

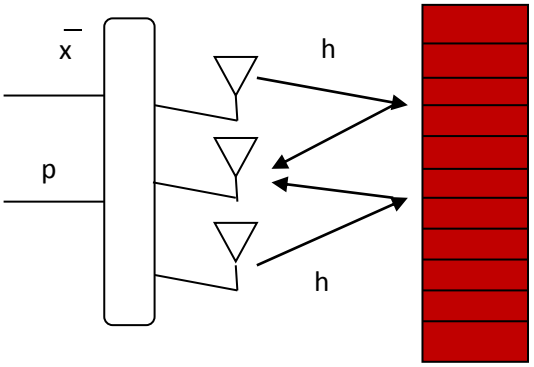


Fig 4: Signal Transmission on First Antenna

3. Wi-Vi uses these channel estimates to compute the ratio p = - h1/ h2. Lastly, the two transmit antennas transmit simultaneously, where the first antenna transmits x and the second transmits px. Therefore, the perceived channel at the receiver is,

$$h_{res} = h1 + h2 [- h1 / h2]$$

Where the estimates h1 and h2 are perfect in the ideal case, the receive signal h_{res} would be equal to zero.

Hence Wi-Vi has eliminated all the signals from the static object as well as the direct signal from transmitting antenna to receiver antenna.

Power Boosting: The next step is to boost the transmitted signal power since only nulling static objects is not enough because the signal reflected by the moving objects behind the wall is too weak. Since, the channel has already been nulled, i.e., hres = = 0. This increase in potential does not drench the receiver's ADC. However, it increases the overall power that traverses the wall, and, hence, improves the SNR of the signal due to the objects behind the wall [3].

Iterative Nulling: Once the transmit power has been boosted the next step is to measure the residual reflections which are below ADC quantization level. If the reflections from the static objects are not removed they create the clutter in the tracking process. And the solution to this issue is Wi-Vi's iterative nulling process.

Here the object is simple, one needs to remove the signal after boosting the power to remove the residual reflections. Separately estimating the channels from both the antenna is challenging because we receive combine channels. And one cannot remove the nulling and re-estimates the channels because after boosting the power, without nulling, the ADC would saturate.

III. IDENTIFYING AND TRACKING HUMANS

After eliminating the impact of static objects, one can focus on moving objects [refers to human beings] but this system in general and it can track other moving objects too.

1. **Tracking a Single Human**

Earlier through-wall systems track moving objects using antenna array. Wi-Vi avoids the usage of the antenna array for the below reasons

a. In order to obtain a narrow beam and achieve good resolution, a large antenna array is required. A large antenna yields to bulky and expensive systems.
b. Wi-Vi uses MIMO nulling, adding multiple antenna would require nulling the signals at each of them. This requires adding more transmit antenna which will make system bulkier and more expensive.

Wi-Vi captures the benefits of an antenna array by avoiding its drawbacks using a technique called ISAR, Inverse Synthetic Aperture Radar. ISAR uses only one receive antenna hence at any point in time the receiver captures a single measurement. When the target moves, he/she

samples the received signal at successive locations in space. This would give a similar impact of an antenna array. By treating consecutive time samples as spatial samples, Wi-Vi can emulate an antenna array and use it to track motion behind the wall.

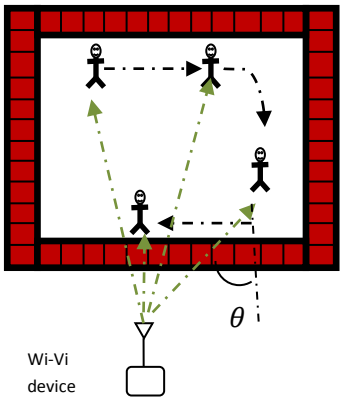


Fig 5: Experimental Setup

Let y[θ] be the signal sample receive from the Wi-Vi device at a different time and n and θ being the angle of abstraction between the channel connecting Wi-Vi device and human. θ is positive if the human moves in the same direction to the Wi-Vi device and negative in opposite direction. Now, one need to determine the measure of the signal along the spatial direction θ at n time, the function is A[θ, n]. In order to determine this value

Wi-Vi processes the receive sample to remove the effect transmitted signal and obtain the channel as

$$h [n] = y [n] / x [n]$$

To emulate an antenna array of size w, it considers w consecutive channels i.e.[n].....h [n + w].

By applying standard antenna array

$$A [\theta, n] = \Sigma_{(k=1)} ^w h [n +i] e^{(j2\pi(1\Delta\sin\theta)/\alpha)}$$

Where α is the wavelength and Δ is the spatial separation between successive antennas in the array.

2. Tracking Multiple Humans

Here Wi-Vi extends its tracking procedure to multiple humans. To track human motion one can emulate an antenna array as in the case of single human tracking discussed earlier. But, each human will emulate a separate antenna array. Since Wi-Vi has a single antenna, the received signal will be a superposition of the antenna arrays of the moving humans. Rather than having one curved line at any time, there will be as many curved lines as moving humans at any given point in time.

However, with multiple humans, the noise increases significantly. Consider first, each human is not just one object but, different body parts moving in a loosely coupled way. Second, the signal reflected off all of these parts is correlated in time, since they all reflect the transmitted signal. The lack of freedom between the reflected signals is important. For example, the reflections of two humans may combine systematically to dim each other over some period of time [3].

Smoothed Music Algorithm can be used to track multiple people. This algorithm computes w x w correlation matrix R[n]. And then an Eigen decomposition of R[n] can be performed to remove the noise and keep the strongest Eigenvectors, which in our case correspond to the few moving humans, as well as the DC value.

Table 2: Comparison between previous papers on Wi-Vi Technology- see through walls

Sl No.	Author Name	Title	Technique	Accuracy	single/multiple identification
1.	1.M Murugan, 2.Mr. G Sathish	A study on future scope of Wi-Vi technology	1.MIMO Nulling 2. WISEE gesture recognizing the system	60%	both
2.	1.Manupalli UmaMaheshwararao 2. Bala Brahmeswara kadaru	See-through wall using Wi-Vi	1.MIMO Nulling 2. Micro-Doppler Signature for gesture base interfaces	(not specified)	Both
3.	1.Mayuri Dharma Shinde 2. Prof. Shailesh Jadhav	Review on Wi-Vi Technology	1.MIMO Nulling 2. Micro-Doppler Signature for gesture base interfaces	(not specified)	Both
4.		A Review on Wi-Vi	1.MIMO Nulling	(not	Both

	1.Rohan H. Patel 2. Arvind G. Thosare 3.Kaustubh U. Pathak	Technology	2. Micro-Doppler Signature for gesture base interfaces	specified)	

Limitations of the Study on Wi-Vi Technology

- According to the paper [6], 60% accuracy can be achieved on simple gestures. But on complex gestures, the same accuracy cannot be achieved.
- The research is concentrating on the identification of human beings, but the system detects the movement of other objects too.
- According to the paper [7], one cannot detect humans behind the wall thicker than eight inches.
- Wi-Vi is a low range resolution device.

Advantages of Wi-Vi Technology

- Wi-Vi is relatively a low power, low cost, and accessible to average users.
- Wi-Vi requires only a few Mhz of bandwidth and operates in the same ranges as Wi-Fi.
- It can perform through wall imaging without trying to access to any device, from the other side of the wall.
- Extend human vision beyond the electromagnetic range, allowing us to detect objects in the dark or in smoke.
- Wi-Vi employees signals whose wavelength are 12.5 cm.

Disadvantages of Wi-Vi Technology

- Display a very low resolution.
- Humans behind concrete walls thicker than 8inches cannot be detected.
- To achieve a narrow-beam the human needs to move about 50 cm.

Applications of Wi-Vi Technology

The Wi-Vi device is used in many areas and the following images will show you the uses or applications of Wi-Vi device.

Fig 6: Real-Time Applications of Wi-Vi Technology

Fig 7: Security-Based Applications of Wi-Vi Technology

VI. CONCLUSION

In Wi-Vi, uses a wireless technology that is Wi-Fi signals to detect moving humans behind walls and in closed rooms. In distinction to previous systems, that area unit targeted for the military, Wi-Vi permits little low-cost see-through-wall devices that operate within the school of thought band, rendering them possible to the overall public. Without carrying any transmitting device, Wi-Vi helps to communicate channel with a human behind the wall and itself. We can think in this way that the way we look Wi-Fi can be an instance for WI-VI. In the next generation of Wi-Fi network, I will not only the mode of communication but can also perform sensing, control and within building indoor localization. Wi-Vi technology helps to manage Wi-Fi based sensing and localization, which helps to track human from behind the wall. It bridges the state of the art networking techniques with the combination of human-computer interaction. It helps to achieve a new form of user interfaces which depend solely on using the reflections of a transmitted RF signal to identify human gestures. By getting optimum leveraging finer nulling technique with the combination of the best hardware, the whole protocol model can help to track human even though the denser building with a longer range. We can predict that the Wi-Vi technology can be a foundation for capturing higher quality image to enable the gesture-based interface, and later it can lead to a new direction towards virtual reality.

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