HOME NETWORKS

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Abstract
To cope up with the attenuation problem, relays or directional antennas with high directive gains can be handle. Both methods have challenges among their benefits. It is verifying through simulation shown that having a relay node in the middle of a 60 GHz network falling off the average free path loss 33% in the wort scenario. When network nodes use directional antennas, the neighbour discovery process becomes more complicated and time consuming. There are not many studies assuming pure directional transmission and reception at all steps of communication. Random selection among sectors is generally used for pure directional communication. To reduce the neighbour discovery time, we propose a smart neighbour scanning algorithm in this work. It is observed that the proposed strategy discovers 70% of the links 81% faster and 90% of the links 15% faster than random scanning strategy for a typical home network scenario. A condition to have a path between any two nodes and a stochastic model to study isolation trend in home networks are also presented. The decision of this thesis impress the multi-hop communication, use of directional antennas for indoor networks.

Keywords: *Smart Scan, Millimeter waves, Probability*

I. Introduction
Home Network (HN) is a residential local area network providing communication between heterogeneous electronic devices deployed in the home. Usually a small number of personal computers and devices are deployed in the network such as printer, mobile computing device, game console and HD TV. Intense allocation and unavailability of large bandwidth at low frequencies such as 2.4 GHz and 5 GHz lead to search for alternatives at high frequencies.

High frequency signals such as millimeter wave signals at 60 GHz have an inherent security feature due to penetration incapability. Hardware which can operate at 60 GHz frequency used to be very expensive compared to WLAN hardware but with recent developments silicon based solutions are possible for 60 GHz devices with WLAN comparable cost.

High data rate, inherent security, scalability and compact size components properties also makes 60 GHz technology a candidate for data cable (e.g. cat5 and HDMI) replacement. Maintaining the network connectivity in a desired quality with 60 GHz links, which are highly susceptible to propagation and penetration losses, is still a major challenge. Behavior of 60 GHz rays are referred as quasi-optical since reflected, diffracted or scattered rays do not contribute received power significantly and most of the energy is provided by direct path.

a) Problem Characterization
Connectivity is one of the major issues for 60 GHz networks due to the fragile nature of the high frequency wireless links. Using relay nodes provides advantages in terms of path loss due to nonlinear relation between distance and path loss. Using a relay device in the network shall be evaluated since throughput of the network would decrease drastically with severe loss when throughput decrease due to relaying is always less than former case.

It is possible to bypass an obstacle and keep connectivity of network via relay**.**

"Evaluate lower bound of relay interest on received power and design of a scanning strategy to fully apply directional antennas in 60 GHz home networks" is the main problem discussed.

b) Contribution
In this work, the contribution of relaying to the physical connectivity of network and application of directional antennas in 60 GHz home networks is investigated. Use of relay nodes implies implementation difficulties which should be compensated by benefits of relaying. Communication of devices starts with handshake among parties which is referred as Neighbour Discovery in the scope of this paper.

A new neighbour scanning method for neighbour discovery algorithm in FHN is planned.

II. Literature Review
60 GHz technology has attracted significant consideration from academia and industry for its probable use in future communication systems. The 60 GHz band is attractive because of the large bandwidth in

the 59-64 GHz license-free spectrum which is globally available. Its physical characteristics also provides defense to co-channel interference, better spatial reuse, high security advantages. It is foreseen to achieve up to 4 Gbps data rate with this technology. The 60 GHz band is promising for future use and its popularity can be perceived in recent standardization achievements. Standardization on higher layer issues of high frequency bands and directional antennas is infant compared to physical layer standardization process.

a) Work Related to Relay

One of the major challenges for the adoption of the 60 GHz technology in the future home networks is the heavy attenuation characteristics of the millimeter waves. A simple 60 GHz device, as defined in the ECMA specifications may lack advanced antenna systems to automatically set up the broken links via reflections; therefore, the reflection-based approach cannot be implemented with simple systems. Another solution to preserve 60 GHz connectivity in case of obstructions is relaying the signal via an intermediate device to the Receiver (Rx).

In general, relaying can be performed in two schemes, amplify-and-forward (AAF) or decode-and-forward (DAF). In the AAF scheme, the relay simply amplifies the signal prior to retransmission. It is a very simple relay solution from the hardware complexity aspect but not efficient for the systems with critical link budgets since the noise is also amplified in this method. In the DAF scheme, the relay regenerates the signals by completely decoding and then re-encoding them before the transmission to the final destination.

The link blocked by a human body or a regular indoor obstacle is thought to be disconnected due to high attenuation of millimeter range wavelength signal. Blockage of a link by a human body cause 20-30 dB reduction in link budget. Although the channel characteristics of 60 GHz band have been extensively studied for last two decades, the multi-hop and relay communication in 60 GHz are not thoroughly elaborated yet. In this thesis, we investigate the eff ect of utilizing relay communication on the 60 GHz link connectivity in indoor settings.

b) Work Tied up with Networking

The link budget is a major handicap of 60 GHz band because of heavy attenuation by distance and limited capability of diff raction around the obstacles. Critical link budget constraint requires the 60 GHz systems to obtain the maximum gains from the antennas, which can be achieved by directional transmission in both ends. Using directional antennas in both ends provides gain about 15-18 dB which almost compensates extra path loss compared to a 5 GHz wireless communication system. Beam steering and use of directional antennas to compensate severe attenuation and multipath are more feasible at 60 GHz given the advantages of short wavelength. The characteristics of the millimetre waves enable the design of highly directive and steerable antennas in compact sizes. Directional networking also has increased spatial reuse, interference and multipath reduction benefits. These provide higher capacity by supporting more simultaneous communications and fewer hops via longer transmission ranges. Decreased multipath leads smaller delay spread and this enables using simpler receivers.

To establish a communication link between two nodes with directional antennas, the antenna beams should be steered to each other along the LoS path or the most dominant Non-Line of Sight (NLoS) path. When the right alignment is provided, the antennas should be in complementary transmission reception modes to discover each other. This issue is referred as directional neighbor scanning problem

Directionality is concerned for MAC protocols and Directional Medium Access Control (DMAC) schemes are discussed in several studies. Distributed and centralized MAC schemes are possible and there are pros and cons for each of them. Distributed scheme is more flexible and allows ad hoc operation better but it is more complicated than centralized scheme. Centralized MAC is less complicated to realize but a superior device like AP is needed to control and organize other devices in the network.

There are few studies considering pure directional transmission and reception during whole communication period. We investigated initial signaling opportunity between network nodes when only directional communication used. We quantify the benefits of location awareness in neighbor discovery process for diff erent network parameters. We also present isolation model and connectivity condition specific for home networks with directional antennas.

III. About Millimetre Waves System

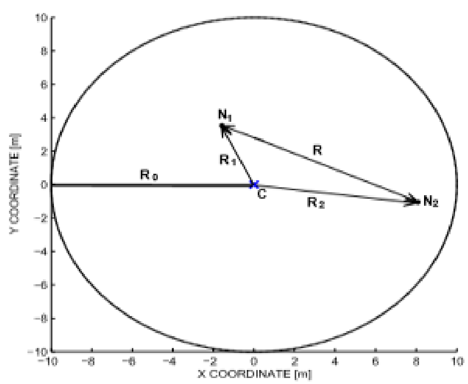
As the name indicates, millimeter wave systems operate on wavelengths in millimeter scale (around 10mm down to 1mm). Wavelength converted to frequency with the relation to speed of light ($f = c/\lambda$) leads to a range of 30 – 300 GHz. This frequency range is also referred as Extremely High Frequency (EHF) by ITU-R.

The big potential of millimeter wave area is that there is more available spectrum than what has been occupied by all wireless communication systems together until today. The main reason of low utilization of the millimeter wave area in the past is the cost of manufacturing the equipment.

IV. Connectivity Rectification With Relaying

Using relay nodes provides advantages on amount of path loss due to nonlinear relation between distance and path loss. Delay imposed by relaying degrades network throughput by a factor of two where throughput degradation due to an obstacle causing 10 dB attenuation is a factor of ten. Decode-and-forward (DAF), amplify-and-forward (AAF) are two schemes for relay mechanisms. In AAF scheme noise penetrates to second relay link since it is also amplified together with communication signal. Although noise is cleared in decoding process in DAF scheme it has more processing load and it imposes more delay compared to AAF. Assuming DAF scheme for relay devices in this study to clear noise at relay, we relate the link quality with amount of path loss in transmission. A circular network area is considered and two cases (with relay and without relay) are investigated analytically to compare amount of path loss and relate it to link quality improvement. Network nodes are assumed to be distributed uniformly in the area of interest and probabilistic models are used for deployment.

a) Testing Model



In this section, an analytical model is presented to model the gains of employing relays in 60 GHz networks in terms of path loss. We devise two scenarios as shown in Figure 3-1. In the first scenario, we consider two randomly deployed nodes directly communicating with each other. We concentrate on the line-of-sight link and calculate the expected path loss as the link quality measure. In the second scenario, the randomly deployed nodes communicate via a relay device positioned in the center of the circular field.

Simulation results closely match with analytical model as can be seen in Figure 3-2. It shows the shape match between derived PDF and histogram which were obtained in simulations. 106 pairs of nodes were randomly deployed in a circular area with radius R_0 in simulation. Distances from nodes to center were measured for each pair and greater one among these two measurements was saved in a vector.

V. Confirmation by Simulation

For scenario without a relay device and with relay device we observed Distance between nodes is found. Path loss is calculated using Frii's Formula for each randomly node pair. Path loss values are stored and average of individually calculated path loss values is found at the end. For relay scenario, distances from each node are calculated and larger one is taken as the limiting factor, determining link quality. Path loss is calculated for this longer link. Then average of these path loss values is found to compare with average path loss without relay device.

These simulations confirmed the results obtained in the analytical model resulting 33% less path loss via relay node. Numeric simulations also provided the opportunity to observe path loss advantage via relay node in rectangular coverage area. Simulations were carried for rectangular areas while keeping these areas within coverage area of the relay device.

VI. Scanning with Directional Antennas

Directional antennas provide the possibility to focus energy of signal towards a certain direction. Deployment of directional antennas in 60 GHz home networks is crucial due to high attenuation of millimetre waves. A 60 GHz communication system sense 28 dB larger free-space path loss than a similar WLAN system regulating at 2.4 GHz. To fully utilize the benefits of directional communication in an indoor network, both ends of a 60 GHz link should have directional antennas with steering capability. Using directional antennas because additional challenges like increased hidden terminal problem and deafness in communication of nodes. Current communication protocols for WLAN systems are designed for omni-directional antennas and they are either inefficient or inapplicable for directional antennas. In this work we focus on Neighbor Scanning which is initial step for neighbor discovery and communication among network nodes. To establish a communication link between two nodes with directional antennas, the antenna beams should be steered to each other along the LoS path or the most dominant NLoS path. When the right alignment is provided, the antennas should be in complementary transmission-reception modes to discover each other. This issue is referred as directional neighbor scanning problem and generally simplified in the literature by using omni-directional antennas in the neighbor discovery phase.

a) Scanning Problem

Algorithms can generally be classified in two groups as direct and gossip-based discovery algorithms. In the direct discovery, two nodes can discover each other if there is a direct transmission between them. In the gossip-based discovery, nodes can carry identity, direction and location information about their direct or indirect neighbors as well as announcing themselves.

Transmitter (TX) and Receiver (RX) are required to confirm discovery by handshaking directly. We consider fully directional neighbor scanning where both TX and RX can only communicate directionally. Directional transmission is common in the literature but reception is generally assumed to be omni-directional. This leads to asymmetrical ranges for TX and RX nodes which worsens hidden terminal problem and causes degradation in throughput. A directional antenna can either be a switch-beam or a beam-steering antenna.

In most of the previous work on fully-directional (both transmitter and receiver have directional antennas) neighbor discovery, beam directions (sectors) are randomly chosen. Nodes determine probabilistically whether to be in transmission or reception states with pre-assigned probabilities. This strategy is called as Random Scan (RS) strategy in the rest of this document. Transmission and reception state probabilities can be optimized for faster discovery in RS strategy. Scanning all sectors by following a pattern or adjusting beam directions based on time information are also proposed. .

In the next, section we propose a smart scanning strategy which takes the node positions into consideration while scanning for neighbors.

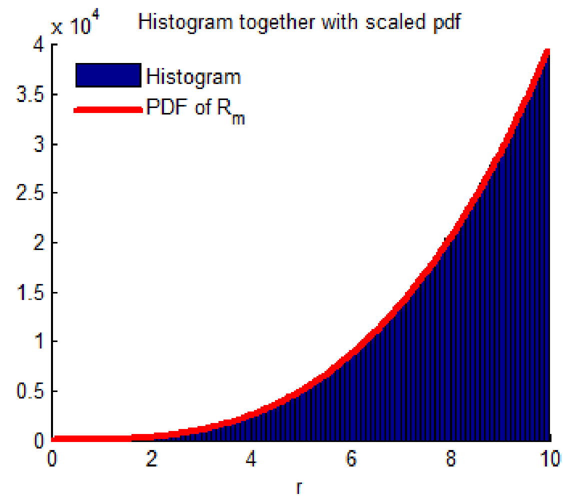
b) Smart Scanning and Locus Awareness

It is a new technology utilize a middle scan server on your network to take burden of your client and reduce amount of traffic. It allow another servers to scan your client. The discovery is successful when the selected sector of the transmitter is aligned with the selected sector of the receiver. According to the transmission states, one of the nodes must act as a transmitter while the other is acting as the receiver. In the RS strategy, the probability of selecting each sector at a search cycle is equal for all sectors. We enhance the RS strategy with the Smart Random Scan (SRS) strategy where the probability of choosing a specific sector is proportional to the area it covers in the room instead of assigning equal probabilities to all sectors.

For calculation of the sector areas, nodes may use present localization methods in the literature to be aware of their location and the environment. With respect to a common indoor references, the nodes may obtain position information themselves. Nodes own locations will be assumed to be known for smart scanning strategy and this is relatively easier than obtaining locations of other nodes in the network. Indoor location awareness methods off er diff erent accuracy in positioning and cost of implementation varies. Technique to calculate the sectoral coverage areas may be the utilization of quasi-optical propagation characteristics of the 60 GHz signals.

VII. Isolation of Network

Defining conditions for connectivity of a network with stochastic methods is cumbersome but isolation of nodes in a network also gives insight about network connectivity. A node is called isolated if it does not have any neighbor known to it. Isolation probability of all nodes in a network is relatively convenient to be investigated. Probability of a node discovering another node in a search cycle in a home network scenario as described in this.

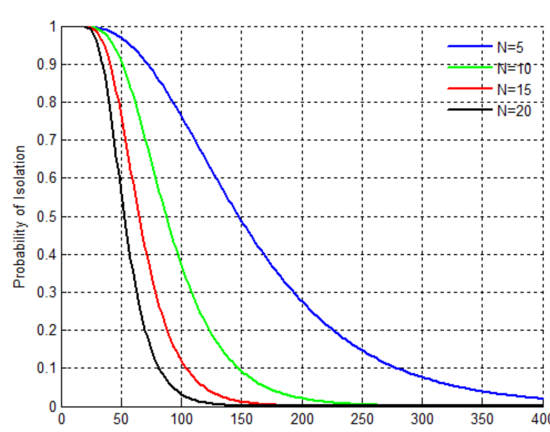


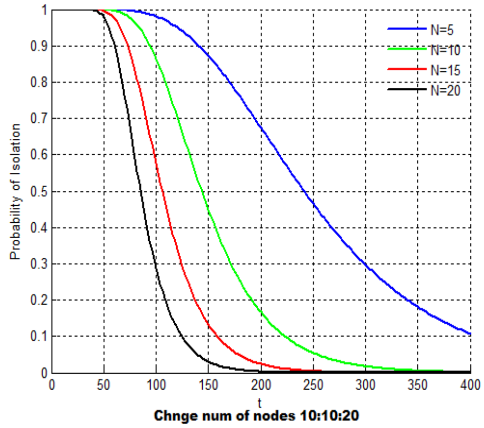
a) Simulation Verification

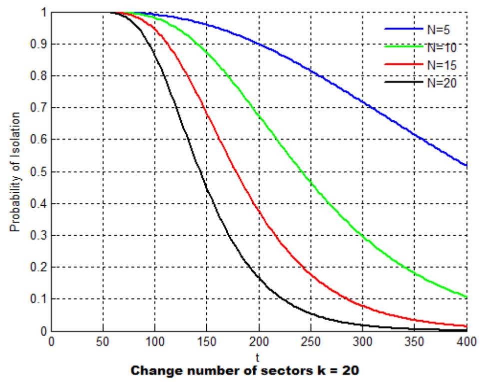
Extensive simulations were executed in Matlab environment to test validity of isolation model. Performance of SRS and RS strategies on releasing network from isolation is tested and compared with each other and with analytical results. Simulation environments were similar to previous performance evaluation simulations but diff erent data which exhibits isolation behavior of network was collected.

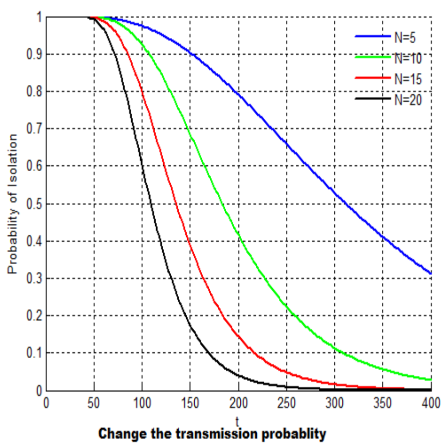
VIII. Results

a) Probability of Isolation

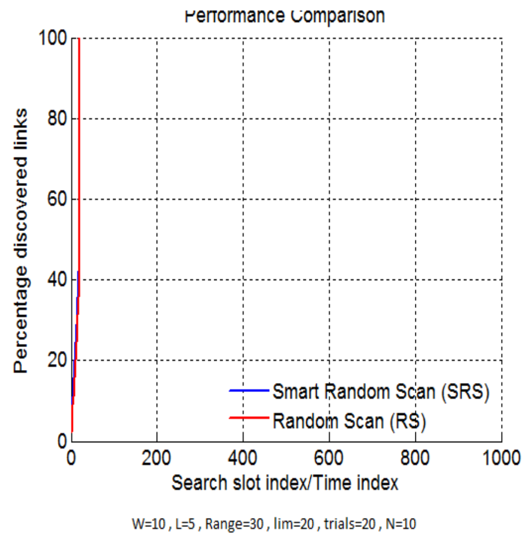


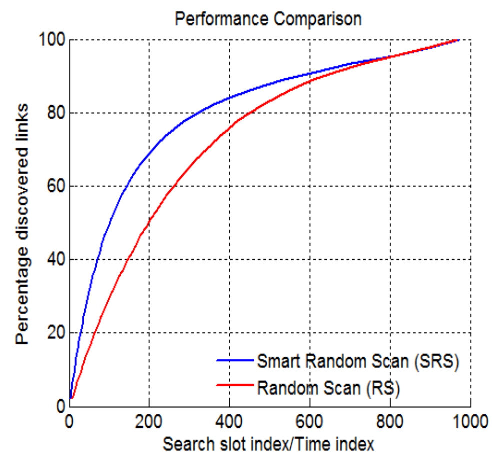






b) RS and SRS comparison





IX. Conclusion

We showed that a single relay device properly positioned in the middle of the network area at the same height with other nodes can reduce path loss 33%. This result motivates the multi-hop communication for 60 GHz indoor networks and two hops are generally sufficient for typical indoor scenarios.

To reduce the directional neighbor discovery time in indoor networks operating at 60 GHz, we proposed a Smart Random Scan (SRS) strategy. It is observed that the proposed strategy discovers 70% of the links 81% faster and 90% of the links 15% faster than Random Scan (RS) strategy for a typical case.

It is observed that SRS strategy always out performs RS strategy in the initial phase of neighbor discovery process whereas SRS has disadvantages on discovery of last few remaining links in the network compared to RS strategy.

As future work, non-uniform deployment of the nodes, the impact of the other influential parameters on the neighbor discovery and the fine-tuning of strategy enhancements such as decision of switching strategies between Smart Random Scan and Random Scan in Hybrid Random Scan can be investigated.

Combining SRS strategy with a gossip-based collaboration scheme to tackle the extreme cases and further reduce the neighbor Discovery duration could be considered.

References

[1] Addison Wasley, Mobile Communication 2nd edition, 2003.

[2] M.Mehta, C.Singh "*1Gbps Wireless Datalink at 60Ghz*".

[3] R.Kokku, R.Mahindra *"60Ghz Data Center Networking Wireless*".

[4] H.T.Friss "*A note on a simple transmission Formula*" Proceedings of IRE May 1946.

[5] R.Mudumbai,S.Singh " *Medium Access Control for 60Ghz outdoor network with highly directional link*" Proceeding of IEEE INFCOM,April 2009.

[6] A.Goldsmith,wireless communication Cambridge University Press 2005.

[7] Adhoc Network "*Fundamental Properties & Network Topologies*",Springer, 2006.

[8] T.S.Rappaport, Wireless communication Principle & Practice,2nd ed. ,Prentice Hall PTR, 2002.

[9] Nan Guo, Robert C. Qiu, "*60-GHz Millimeter-Wave Radio"* article, 2006.

[10] Ines Carton, Jesper Ø. Nielsen, "*Measured wideband characterstics of indoor channel at centimetric and millimetric band"* springer, 2015.