Parameterized Fuzzy Measures Decision Making Model Based System to Minimise Path Loss Problem in Wireless Communication Systems

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Abstract: In this paper we introduce topics related to the radio waves used for transmitting data in wireless communication systems. We will start with the spectral bands then we will delve into the physical mechanisms that facilitate the propagation of radio waves, starting by the simple case where no obstacles are interposed between the transmitter and receiver. Furthermore, we will explain how the waves may be reflected by walls and other surfaces. We will also discuss how they can penetrate through obstacles. Finally, we will introduce simple practical models allowing to calculate the path loss to radio spectrum. Then the trained system incorporating the PFMDMM based Decision Making model correctly classifies the signal based on the minimal path loss.

Keywords: Fuzzy system; wireless communication; BPNN; Decision Making Model; Path loss detection; Preference Levelled Evaluation Functions; RSS; SNR

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INTRODUCTION

Spectrum allocation is the domain of Commandment agencies for example the Federal Communications Commission in the USA, the Ministry of Internal Affairs and communication from Japan, the Frequencies National Agency (ANFR) in France and the State Radio Regulation Bureau from China [1]. At the international level the United Nation holds a specialized agency called International Telecommunications Union called ITU [2]. One of its branches called ITU-R focuses on radio matters [3]. It develops recommendations that are suggested to national bodies as guides for spectrum regulation purposes. ITU-R meets every four years in the world radio communication conferences. In 2015 it raised questions regarding the 5G spectrum. The main concern in the design of communication systems is how to ensure that the different components are able to understand the respective messages. In other words, to ensure that all components interoperate properly. Since 1998 the third generation partnership project 3GPP has developed the detailed requirements that all pieces of equipment and software must comply with [4] in order to ensure that they work smoothly together. 3GPP provided the specification for 3G UMTS and for 4G LTE systems. Since 2016 it works on the development of 5G. 3GPP 5G bands are arranged in two groups the first one covers the range between 450 GHz and 6 GHz. It is the domain of the centimeter waves [5]. The second one covers the interval between 24 and 53 GHz called the millimeter block. Some of the centimeter bands are in use for mobile communications since a long time ago. For example, band 1 is being used in Europe for 3G. Bands 7 and 20 are used in 4G. These bands will probably be refunded for 5G sometime in the future. On the other hand, millimeter bands have not been used for cellular communications up to now. Due to their high frequencies, they behaved differently than the centimeter ones [6].

Friis Free Space Propagation Model

As a starting point let's consider radio waves propagation when there are no obstacles interposed between the transmitter and a receiver and no reflections or diffraction effects take place [7]. The signal produced by the radio amplifier at the transmitter is attenuated by the transmission cables, connectors and other accessories feeding the antenna which provides additional gain. Radio waves flow from transmitter to receiver. The signal captured by the receiver antenna is attenuated by its conduction line. The resulting signal feeds the receiver front end.

Let's call g_t on $g_r$the gains of the transmitter and receiver antennas. l the transmission losses in the internal lines. $\lambda$the wavelength of the transmitted signal and d the distance between the transmitter and receiver. Repeat p_t be the transmitted power in words and p_r the received power the ratio between p_t and p_r may be compute by Friis equation [8] given below.

$$\frac{P_r}{P_t} = \frac{g_t \cdot g_r}{l}\left(\frac{\lambda}{4\prod.d}\right)^2 (1)$$

Lumping sum terms, we arrive at a compact expression

$$\frac{P_r}{P_t} = \frac{K}{(\frac{d}{\lambda})^2} (2)$$

As may be seen the power loss increases as the square of the distance over wavelength ratio.

We focus our attention on a 5G radio wave in the centimeter spectrum region; for example, in the 2100 MHz band. Both will be the power loss if both antennas have unity gain and the distance between transmitter and receiver is 100 meters and the wavelength is 14 centimeters. With the equation (1) we may find the power loss. It amounts to 79 dB. As a second example, consider the 5G millimeter wavelength spectrum region located in the United States with the Federal Communications Commission. It includes bands in 28, 37, 39 and 60 GHz [9]. What will be the power loss if both antennas have unity gain and the distance between transmitter and receiver is 100 meters? Take for example waves transmitted at 28 GHz has the corresponding wavelength is 11 millimeters. Applying Friis equation, we find that it is 101 dB. Although the radius of current typical cells in urban environment is around 500 meters, we expect 5G millimeter cells to be smaller. Probably in the range of 100 meters .at this distance from the base the attenuation at 28 GHz will be 23 dB higher than at 2GHz. When we will discuss antennas for millimeter waves, we will see that it is feasible to compensate this excess attenuation with suitable antenna gains.

Millimeter waves refraction and penetration

We know from daily experience that radio waves are able at some extent to penetrate through walls and other obstacles interposed on the way[10]. Inevitably part of the energy from the incoming wave is reflected or consumed as heat in the obstacle. We say that there is an excess loss over free space attenuation[11]. Research shows the excess loss increases significantly with frequency. Bands on the order of 900 MHz are currently used in 2G, 3G and 4G while millimeter bands near 29 GHz will also be used in 5G. Therefore, we should expect as much as 22 additional dB penetration attenuation under those conditions certainly a major difference. Penetration losses not only depend on carrier frequency. The type of material strongly influences the level of these losses as well. At 29 GHz for example the penetration loss due to clear glass and drywall to typical indoor materials are relatively modest on the order of 5 dB. But for tinted glass as used in the windows of most of his buildings it climbs to around 40 dB [12]. Besides some materials behave at some extent like mirrors. Part of the wave energy bounces back leading to a reflection effect. In millimeter waves the relative strength of this reflected energy is high. For example, around 90% of the energy from 28 GHz waves is reflected by tinted glass [13]. The different behaviour between centimeter and millimeter waves leads to advantages and inconveniences for 5G. On one hand, attenuation largely increases at 29 GHz and beyond reducing the coverage of 5G base stations. Therefore, additional cells will be required to cover a given area. On the other hand, strong attenuation from the tinted glass as used in outdoor walls reduces interference between indoor and outdoor cells facilitating frequency reuse. As a spectrum is a scarce and expensive natural resource increased efficiency is welcomed by carriers in regulatory agencies. Moreover, building walls and tinted glass windows are good reflectors of millimeter waves [14]. Therefore, the user equipment might be able to receive signals from these secondary sources even if the direct site to the base is obstructed.

Path loss

Let's recall the Friis equation from our previous discussion on free-space propagation. If we set aside two terms related to antenna gains and cable losses a factor including the dependency on base to mobile distance and wavelength is left, we call it path loss. Path loss may be expressed in decibels [15]. It includes the term ∞ which only depends on the selected wavelength and another one β which exclusively depends on the base to mobile distance. Therefore, the resulting linear equation includes just two parameters; the intercept ∞ and the slope β. In real situations the free space model does not reflect the propagation mechanisms with sufficient accuracy. There are several reasons for this limitation. A direct line-of-sight wave reaches the receiver. But one or more reflections reach it as well. The line-of-sight wave is blocked by an obstacle. But the receiver is able to get sufficient energy from one or more reflected waves. The path loss equation previously discussed remains a good graph approximation in these situations. But different values of the intercept and slope must be used.

We notice a weak wireless performance in places where this kind of path loss situation is not avoided. Even after removing many obstacles the access points will not always enhance the wireless performance due to such path loss issues. reflections are one of the reasons for this. If more wireless devices work in the same proximity, it may result in reflections problem and will reduce the performance. This paper proposes a BPNN model that is using PFMDMM (Parameterized Fuzzy Measures Decision Making Model) clustering method to identify such path loss problems by the distribution points and to give preference to the best suitable distribution point to give the service to the access points.

THE BACKGROUND

Path loss in wireless networks

Path loss is the attenuation of an RF wave as it travels away from the transmitter antenna. It is a measure of dilution of the waves' energy as it expands in space [16]. While the signal strength is decreasing with distance, the path loss is growing and corresponds to the inverse of the signal strength. Path loss is part of the link budget equation and it not only increases with distance but also with frequency. Moreover, it grows exponentially, with the power of 2. Wireless Internet Service Provider (WISP) often uses the 2.4 GHz spectrum, because it is license free and the RF wave travels further than higher frequency signals. The 5 GHz spectrum which is unlicensed as well has somewhat higher path loss which can result in more hardware needed to cover the same area as with 2.4 GHz gear. The 60 GHz spectrum shows a great promise for future networks with gigabit speeds but has a much higher path loss, which enables around 2 km link distance at best, considering the state of the art of today's hardware. Path loss should definitely be considered while deciding which part of the spectrum to use. But the decision goes well beyond the simple physics of achievable distance. At 2.4 GHz, the waves travel far, but the huge number of other devices operating in the same bandwidth generates enough interference to clutter the spectrum making the network highly unstable and unreliable. At the same time, the throughput speeds achievable in the limited bandwidth are increasingly insufficient for today's growing demand. At 5 GHz, the path loss is about 7 dB higher, so the RF waves do not travel as far, which can be an advantage acting as natural protection against interference. But despite the shorter achievable distances, the 5 GHz spectrum is quickly headed towards the same interference saturated state as the 2.4GHz networks. At 60 GHz, the path loss is about 28 dB, or, about 700 times higher than at 2.4 GHz. Combined with the wide bandwidth available, the possibilities for future multigigabit networks are vast, but, only in densely populated areas due to the shorter achievable distances, which also makes for a naturally high security network.

The spectrum that the best for WISP networks

There is no perfect solution that fits every situation, every choice comes with a tradeoff, due to the principles and limitations just described. Strength in one place, can be a weakness elsewhere and vice versa. But the awareness of the path loss and this short summary of the main properties is a good starting point when designing our next link.

Preference Levelled Evaluation Functions Method to Construct Fuzzy Measures

This study considered the following 5 GHz (802.11b/g/n/ax) range WLAN.

Table 1: 5 GHz channels considered for this study

Channel(x)	Frequency(F) (MHz)	Frequency range
36	5180	5170–5190
40	5200	5190–5210
42	5210	5170–5250
48	5240	5230–5250
50	5250	5170–5330
52	5260	5250–5270
56	5280	5270–5290

60	5300	5290–5310
64	5320	5310–5330

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Parameterized fuzzy measure identification

We have the normalized weights function $b = B^{<x>}$. $\hat{\lambda}_b \epsilon [0,1]^x$ is its complementary preference.

(F, 2^F, t_X) be a given fuzzy Frequency measure space where F= {x(1), ..., x(n)}, where x is 5 GHz the channel values from sunysb/multi_channel dataset (v. 2009-02-24) dataset that is mentioned in Table 2.

B, $B^{<x>}$, t_X are bandwidth, corresponding x-ary aggregate function and the space of all fuzzy measures on X respectively [17][18].

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Intention: Parameterized fuzzy measure $t_G^{\phi_1,\ldots\ldots,\phi_s}$identification for parameterized fuzzy measure space (G, 2^G, $t_G^{\phi_1,\ldots\ldots,\phi_s}$) where G = {1, ..., x}

Step 1:φ : $G \rightarrow ([0, 1]^n)$ (3)

Where($[0, 1]^n)^G$ the space of all mappings.

Step 2:$t_G^{(b,\phi)}$: $2^G \rightarrow [0, 1]$; for any $C \in 2^G$ ($C \neq \varphi$), we have

$$t_G^{(b,\phi)}(C) = t_F(\{f \epsilon F \mid (\vee_{g\epsilon C}\ \phi(g))(f) \geq \hat{\lambda}_b(|C|)\}) \qquad (4)$$

Step 3: define adjustability conferring to an expected preference b *i.e*$t_G^{(b,\phi)}$ (ϕ) = 0 for all b and ϕ.

It is note that complementary preference $\hat{\lambda}_b$aid as diverse thresholds to be surpassed by union assessments $\vee_{g\epsilon C}\ \phi(g)$.

Step 4: when $C = G$, it follows $\{f \epsilon F \mid (\vee_{g\epsilon C}\ \phi(g))(f) \geq \hat{\lambda}_b(|C|)\}$ = F,

then $t_G^{(b,\phi)}(G)$) = 1, always. (5)

It is note that, usually the greater conservativeness, the lesser the parameterized fuzzy measure $t_G^{(b,\Theta)}$

($B^{<x>}$, ≺) gives a whole lattice with ordering ≺ demarcated such that for any two b, $b' \in B^{<x>}$,$b \prec b' \Leftrightarrow \lambda_b \prec \lambda_{b'}$ [17].

Step 5: For a pair of b, $b' \in B^{<x>}$, if $b \prec b'$, then λ_b (j) = $\sum_{m=1}^{j} b(m) \leq \sum_{m=1}^{j} b'(m)$ = $\lambda_{b'}$(j) for all $j \in$ {1, ..., x}.

Step 6:

$$cn(b) = \sum_{j=1}^{x} b(j).\frac{j-1}{n-1} = \frac{1}{x-1}\sum_{u=1}^{x}\sum_{m=s}^{x} b(m) = \frac{1}{x-1}\sum_{u=1}^{x}[1 - \sum_{m=1}^{u-1} b(m)]$$

$$= \frac{1}{x-1}\sum_{u=1}^{x}[1 - b(u) - \sum_{m=1}^{u} b(m)]$$

$$= \frac{x}{x-1} - \frac{1}{x-1} - \frac{1}{x-1}\sum_{u=1}^{x}\sum_{m=1}^{u} b(m)$$

$$= 1 - \frac{1}{x-1}\sum_{u=1}^{x}\sum_{m=1}^{u} b(m) \geq 1 - \frac{1}{x-1}\sum_{u=1}^{x}\sum_{m=1}^{u} b'(m) = cn(b') \qquad (6)$$

Where *cn*, the relation about conservativeness [19]

Step 7:

for any two C, C' ∈ 2^G with C ⊂ C', $t_G^{(b,\phi)}(C)) \leq t_G^{(b,\phi)}(C'))$; (7)

for any two b, b' ∈$B^{<x>}$ with b ≺ b', $t_G^{(b,\phi)}$(C) ≤ $t_G^{(b',\phi)}$(C); (8)

for any two ϕ, ϕ'∈ $2^F)^G$ with $\Theta<\Theta'$ (here "<" is ϕ(j)<ϕ'(j) for all *j*∈ G),

$$t_G^{(b,\phi)}(C) \leq t_G^{(b,\phi')}(C). \quad (9)$$

Result: With the factors identified on G = {1, …, *x*} of sunysb/multi_channel dataset (v. 2009-02-24) dataset we can express which signal is more likely to give data of better quality and which is more likely to give erroneous data with the help of BPNN.

Readers may refer the paper [20] for proof of the equations (3) to (9).

PROPOSED MODEL

The proposed Back Propagation Neural Network model incorporating Decision Making Model Based on PFMDMM for best Signal Detection based on minimal path loss is depicted in Figure 1.

The system will be fed with spectrum of 5 GHz range with an intention to find the best signal range having minimal path loss. The power loss on fed spectrum will be calculated with Friis equation [21]. The Path loss identification with PFMDMM will be done next. In the training stage, weights of the classifier are given with some ideal values for bootup as per {SNR, RSS} History as prided in the sample values in Table 2. A set of samples values based on the weights would be tuned to identify the best signal value during the iterative learning procedure with the help of BPNN algorithm. In the testing stage, the BPNN is tested against a range of test samples of signals on {SNR, RSS}. This will make sure whether trained system correctly classifies the signal based on the minimal path loss. This will identify the best signal based on minimum Path loss.

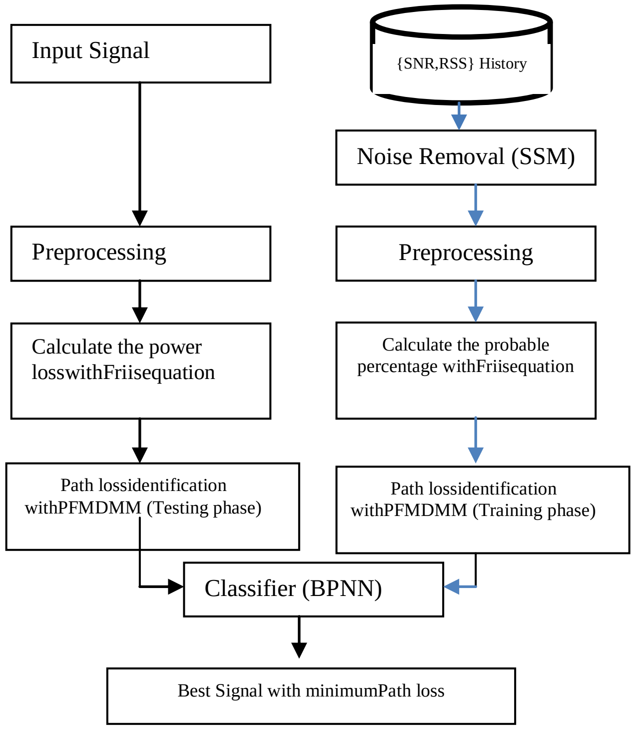

Figure 1. Block diagram of proposed PFMDMM for Best Signal with minimum Path loss.

Algorithm 1: PFMDMM based Best Signal Decision Making Model with nrespect to minimum Path loss

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Input: Feed spectrum of 5 GHz range signals.

Output: identifies the Best Signal with minimum Path loss.

Start

1. Feed spectrum of 5 GHz range.
2. Calculate the power loss with Friis equation
3. Path loss identification with PFMDMM
   a. *Training stage:* weights of the classifier are given with some ideal values for bootup as per {SNR, RSS} History. The weights would be tuned to identify the best signal value during the iterative learning procedure with the help of BPNN algorithm.
   b. *Testing stage:* the BPNN is tested against a range of test samples of signals on {SNR, RSS}. This will make sure whether trained system correctly classifies the signal based on the minimal path loss.

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4. Identify the best signal based on minimum Path loss.

Stop

Signal Range Detection

Readers can refer to the steps for Friis Equation method in [21].

Backpropagation Neural Network (BPNN) for Best Signal Selection

BPNN basically employs a deep neural network or DNN in the core of this structure. BPNN employed here will improve the accuracy of path loss detection of wireless signalsin each iteration (each iteration is an improvisation of its learning). we use the sunysb/multi_channel dataset (v. 2009-02-24) dataset [22] used as the training datasets. These datasets are fed to the BPNN model for based on the learning rules. For the path loss detection, the set of Inp= {SNR, RSS} will be given to the learning module. The output of the system mentioned in the Figure 1 will be the Identified best signal based on minimum Path loss. Care must take to feed enough data sets from sunysb/multi_channel dataset (v. 2009-02-24) for the deciosn making system to make a fair model to detect an accurate signal with path loss. Under the test conditions the trained model with sunysb/multi_channel dataset (v. 2009-02-24) dataset on BPNN provided best permeates for any Access point.

EXPERIMENTAL RESULTS

The implemented model devised in MATLAB that is employing PFMDMM algorithm identifies the best wireless signal based on the minimum path loss factor. Input channels of 36, 40, 42,48,50,52,56,60 and 64 from 5 GHz is fed to identify the minimum path loss in signals. Path loss detection is done with Friss equation [20]. Then, Parameterized Fuzzy Measures Decision Making Model clustering method (PFMDMM) is employed to identify the signals with minimum path loss. At the initial stage of training stage, the BPNN were given with some arbitrary values from Table 2. The trained values in the models would be tuned to the best values in each iteration of BPNN with the help of back propagation algorithm. The PFMDMM is used to obtain efficient and speedy best signal detection of an architecture. The study claims that for path loss detection and in turn for best signal suggestion, the system is 91% efficient in average case.

Data Source

The study uses the sunysb/multi_channel dataset (v. 2009-02-24) dataset provided by Community Resource for Archiving Wireless Data at Dartmouth (CRAWDAD) [22]. 802.11g and 802.11a Data sets consisting of measurements from two different wireless mesh network are available in this testbed of three folders namely multi_channel_data_set [802_11a (1014 files), 802_11g (1014 files) and interface (320 files)]. The transmit powers are fixed to 15 dBm and data rate to 11 Mbps. Measurements from this testbed were collected on 54 different links on three orthogonal channels 1, 6, 11 (2412, 2437 and 2462 MHz respectively) in the 802.11g band. The 802.11a testbed consists of 13 nodes.

The data set mainly provide two information - {SNR, RSS}, that is packet Received Signal Strength (RSS) and Signal to Noise ratio (SNR). A subset of the content of sunysb/multi_channel dataset (v. 2009-02-24) is given in Table 2.

Table 2: subset of the content of sunysb/multi_channel dataset (v. 2009-02-24)

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MAC_TIME_STAMP	**PACKET_TYPE**	**CHANNEL**	**SNR**	**RSS**	**NOISE**	**DATA_RATE**	**MAC_SEQUENCE_NUMBERS**
7841718	Data	165	15	-80	-95	6.0	2006
7861843	Data	165	14	-81	-95	6.0	2011
7892953	Data	165	14	-81	-95	6.0	2019
7919931	Data	165	15	-80	-95	6.0	2026
7998391	Data	165	14	-81	-95	6.0	2046
8080765	Data	165	14	-81	-95	6.0	2067
8100607	Data	165	14	-81	-95	6.0	2072
8104992	Data	165	14	-81	-95	6.0	2073
8123619	Data	165	14	-81	-95	6.0	2078
...	...	...	...	...	...	...	...

CONCLUSION

In summary ITU-R and 3GPP recommend 5G radio bands in the centimeter and millimeter domains. 5G radio waves are subject to stronger attenuation than their 3G and 4G counterparts. They are efficiently reflected by tinted glass concrete and other modern building materials. Therefore, reflection becomes a significant propagation mechanism in the outdoors environment. A simple model can be used as a first approximation to predict the expected path losses in direct or obstructed visibility. Excess attenuation is a major challenge due to its economic impact on the radio network infrastructure costs due to path loss. This study claims that this is the first study making use of PFMDMM to identify the signals with minimum path loss.

Specifically, the main contributions of this study are:

- We propose a new use of PFMDMMto identify the signals with minimum path loss.
- For experiments, a sunysb/multi_channel dataset (v. 2009-02-24) datasets are used to evaluate the the models to identify and the path loss. The datasets contained the 5GHz Wireless channels based on 802.11g and 802.11a.

Specifically, we propose an automated signal suggestion model by employing the decision-making capabilities of New Interval NeutrosophicHamacher Power Choquet Integral Operators based Fuzzy Functions.

DATA AVAILABILITY

The data used to support the findings of this study are available from the corresponding author upon request.

DISCLOSURE

This study was performed for the academic purpose of Department of Computer Science, Government Arts College, Salem-636007, India and Department of Computer Science and Engineering, Rajiv Gandhi University, Rono Hills, Doimukh - 791112, India.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this paper.

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