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Research paper

Capacity Enhancement for the Vehicular Network using Spatial Multiplexing

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Abstract

Vehicular Ad hoc Network (VANET) is an advanced system and subcategory of a Mobile Ad hoc Network (MANET), it has as the potential to significantly impact road safety and improve traffic by providing critical information to drivers on critical routes. The system can inform the driver of a local anomaly, which is a very short distance from the sensors. Data from this sensors can be passing between vehicles so as to increase awareness of this environment. Intelligent Transport System (ITS) applications will include traffic efficiency, comfort of driving and road safety. The transaction of warning messages exploits a limited capacity because these applications generate little separate messages. Estimating the capacity of the VANET is therefore essential, as it may limit the deployment or usefulness of these applications. Therefore, an estimate must be made in advance for application design with capacity limitations in mind. VANET capacity is limited mainly through spatial reuse. Multiple-Input Multiple-Output (MIMO) structures have been suggested to replace the conventional systems. In MIMO systems, a much higher data rate can be achieved than in a VANET environment. The objectives of the paper to study the capacity of the VANET network associated with new promising MIMO technology. Spatial multiplexing (SM),utilizes the spatial dimension to maximizethe capacity of a link without expanding a bandwidth. The SM gain is achieved throughtransmitting signals concurrently on parallel channels spatially with the same frequency. Capacity calculated over VANETs environments with MIMO/SM techniques, using Rayleigh Fading Channel with BPSK modulation. The results of MATLAB simulation package 2017a, indicate the enhancement in the unit of bit per second per Hertz (b/s/Hz). A maximum capacity improvement for MIMO system over Single Input Single Output (SISO) was achieved by using (4 x 4) system, it is about 16.14 b/s/Hz.

Keywords: *VANET, MIMO, Spatial Multiplexing, Channel Capacity.*

1. Introduction

With an increasing number of the Internet users and the steady growth in a number of computing and communication devices, a demand to the large data transfer rates is increasing, wireless communications currently represent the fastest growing part of the telecommunications industry[1]. In recent years, telecommunications researches has seen extraordinary evolution, A new promising technique arising from regulating the communication between vehicles, termed as VANET, Wireless systems continue to seek higher data transfer rates that are equivalent to an increase in demand [2], [3]. This is a particular challenge for systems with Limited bandwidth and power. Any increase in bandwidth or power will affect other systems in same area or that uses close spectral channels in negative manner. When the power and the bandwidth are commonly controlled, then the capability of the structure to provide any rise in its performance or its capacity will be limited [4]. Regulating the consumed power and bandwidth will result in systems with limited ability to improve the system performance as well as the system capacity[4], [5]. These challenges might be addressed using of multiple-antennas on both ends of the radio link (i.e., a multi-antenna system) to meet the increasing demand for data, which provides greater capacity gains than single antenna systems through the channel [6].

2. Background

2.1. VANET Standards

Dedicated Short Range Communication (DSRC) protocol was established to support ITS communication applications for such VANETs by the United State Federal Communication Commission (FCC) [7]. DSRC protocol united by Institute of Electrical Engineering and Electronic (IEEE) in 2004 and classified as IEE 802.11p standard [8]. Wireless Access for Vehicular Environment (WAVE) produced by IEEE, it considers the heart of DSRC protocol to fast-moving vehicles. Fig. (1). show structural WAVE design, It comprises both IEEE. 1609 standard and IEEE.802.11p standard, IEEE. 802.11p releasing the physical (PHY)layer and Medium Access Control (MAC)layer specifications for enabling communication at 5.9 GHz band, in vehicular network, while the IEEE 1609 standard participate with the IEEE 802.11p standard for enhancing WAVE suite specifications for further layers [9].

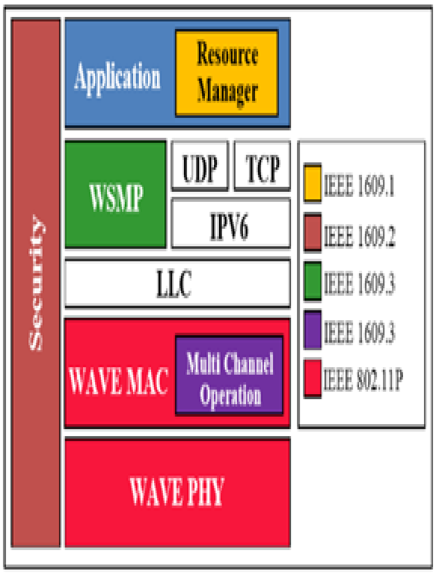

Fig. 1: WAVE Protocol Stack [10]

2.2. Benefits of MIMO in VANETS

MIMO offers the following key benefits to VANET systems: MIMO is the most suitable for various applications and scenarios: The multilateral MIMO approach makes it a key tool in enabling VANET communications. This manifested in the power to configure multiplied antenna array in various modes, rely on the dense interference versus sparse network, multipath propagation environment from scattering richness, most importantly the VANET application of interest, in order to meet the strict requirements for safety and user experience acceptable for information and entertainment applications. SM would best suite high data rate applications, For example, media streaming. Diversity is better for safety applications which impose reliability for warning messages over channel communications. As well, transmit beam forming can be applied to focuses the signal spatially, so, the range of communication extended significantly for the same power of transmission. This particularly useful in highways and rural environments where vehicles density may be lower than others low. MIMO exploits a high dynamic V2V channel: the channel is highly fluctuating because of multipath, which occurs in a sparse, scattered environment, for example, urban area [4],[10].

3. Spatial Multiplexing

SM technologies transmit independent data streams at the same time (simultaneously) named layer, via MT number of transmitter antennas. Thus, whole bit rate comparing to the system with single antenna, thus is improved by MT factor without having to increase the bandwidth or the power of the transmission. The obtained gain from multiple antennas is called multiplexing gain in term of bit rate. Compared to single antenna system. It was the first multiplexing receiver to be prototyped models and created at Bell Labs known as BLAST [11]. There are two architectures of BLAST, the Vertical BLAST (V-BLAST), and Diagonal BLAST (D-BLAST). V-BLAST and D-BLAST encoders are similar. In D-BLAST, before transmission, all signal shifted in time, the shifted in time increasing the complexity of the decoding process. While in V-BLAST architecture, all signals in a separate layer are transmitted from the similar antenna. The data transmitted simultaneously in multiple streams in a single band, then the system capacity directly increased with increasing number of antennas, V-BLAST consequently used to decrease the decoding complexity of the D-BLAST architecture [12]. In this research, the V-BLAST is deliberated.

3.1. Structure of Transmitter and Receiver

The principle of SM is: In a transmitter, the data chain (bits) subdivided to MT sub-strings, then the information is transforming by modulation method and simultaneously transmitted via multiple antennas using the same frequency band. On the receiver side, the received data series is isolated by applying the interference cancellation algorithm [13]. Fig. (2) Clarify SM structure.
The transmitted signals from different antennas spread through separate paths independently and interfere with each other at reception. There is a different algorithm for the detection process at the receiver, which has distinguished by tradeoffs between complexity and performance. The least complex option is the use of a linear receiver, usually the performance of the error is poor, and generally, MR ≥ MT is needed to discrete data streams received reliably. Though, when number of antennas at receiver surpasses the number of antennas at transmitter (MR ≥ MT), the gain of spatial diversity is accomplished [14], [15].

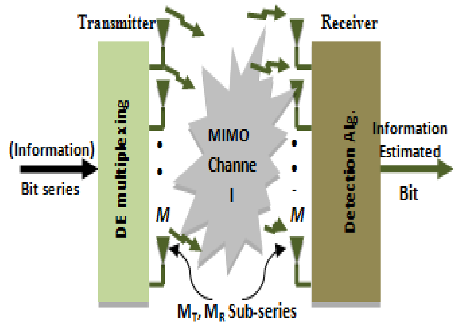

Fig. 2: SM structure [13]

3.2. Spatial Multiplexing gain

MIMO provide the increasing in data rate via SM. Which, transmitting data streams, separately multipliedwithin the same B_w. In suitable conditions of channel, like rich scattering situation, which are widely available in vehicular networks, and frequently found in urban environment, the data streams separated by the receiver. In addition, each stream experience the similar quality of the channel that the SISO system knowledgeable efficiently, capacity enhancing by a multiplex factor equivalent to number of stream [14], [26].

4. Channel Capacity for Multi-antenna Systems

As is known, capacity of the channel is defined as the maximum probable of transmission degree so that the possibility of the error is randomly small. In 1948, mathematical basics for the transmission of information were recognized by Shannon. In the situation of an Additive White Gaussian Noise (AWGN) channel, derive most known form of capacity of the channel, which specified by [16]-[18]:

$$C = B_W \log_{.3}\left(1+\frac{E_s}{N_0}\right) \quad (1)$$

Where C represent capacity of the channel on bit. persecondi, BW, represent a bandwidth of the channel. in .Hertz (H,z), E,s, represent all energy of transmission, and N0 represent spectral density of noise power, that corresponding to over-all power of noise allocated by corresponding to Bw noise (which N0=N / B,W). Besides AWGN, the wireless communication channels are under other deficiencies (i.e., fading), it decreases the capacity of the channel considerably. Thus, the capacity modified as follows [17], [19].

$$C = B_W \log_{\cdot 2}\left(1 + \frac{E_s}{N_0}|h|^2\right) \quad (2)$$

Where $|h|^2$ represent, average of channel gain.Channel capacity degraded significantly in deep fading conditions. Channel state information (CSI) plays a significant part in the transmitter for increasing the capacity of channel in MIMO system andMISO system, however it is difficult to acquire. Anywise, in the receiver, CSI can be gained via training sequence process [17].

1. SISO system

In SISO systems, astandardized Shannon formula for capacity perB_W =1Hz of such structures is specified by [19]-[21]:

$$C = \log_{\cdot 2}\left(1 + \frac{E_{\cdot s}}{N_0}|h|^2\right) \quad (3)$$

Which C representcapacity in [b/s/Hz] of B_W. The restriction of SISO systems is that increases of capacity is slow with a logarithm of signal to noise ratio (SNR), andin general it low [19].

2. SIMO system

SIMO has a single antenna in transmitter and more than one antenna on receiver.Since this system has only one antenna for transmitting, CSI in transmitter does not provide any capacity increase. Therefore, derived capacity can be as [17], [22]:

$$C = \log_{\cdot 2} det\left(I_{M_R} + \frac{E_s}{N_o}H^H H\right) = \log_{\cdot 2}\left(1 + \frac{E_s}{N_o}\sum_{i=1}^{M_R}|h_l|^{12}\right) \quad (4)$$

$H^H, H = \sum_{i=1'}^{M_R}|h_l|^2$, that a sum of all channel gains for antennas in the receiver side [35]. If the elements of channel matrix are identical as well regularized as: $|h_l|^2 = .. = |h_3|^2 = \cdots |h_{M_{,R}}|^2 = 1$, therefore the capacity matches [13].

$$C = \log_{,2} det\left(1 + M_{,R}\frac{E_s}{N_o}\right) \quad (5)$$

Thus, using the multi-antenna receiving system can achieve an increase in M_R capacity in relationwith SISO system. Therises of SNR is identified as array gain [11].

3. MISO system

MISO has a multiple transition antennas and one only antenna in the receiver side.WhileCSI does not obtain at transmitter side, the power of transmission evenly shared between all transmitting antennas (M_T). Thus, channel capacity set by [23]:

$$C = \log_2\left(1 + \frac{E_s}{M_T N_o}\sum_{j=1}^{M_T}|h_j|^2\right) \quad (6)$$

Which$\sum_{j=1}^{M_T}|h_j|^2$ is channelgains summation to all antennas.It is essential to observe that there is no array gain found in the diversity of transmission. Distinctfromthe case of the receiver diversity (SIMO), the total number of received (SNR) is increasing by the gain of the array. However, after a CSI is identified to sender, MISO system capacity becomes [23]:

$$C = \log_{\cdot 2}\left(1 + \frac{E_s}{N_o}\sum_{j=1}^{M_T}|h_j|^2\right) \quad (7)$$

Thus, MISO system capacity is equal to SIMO system capacity when CSI is obtained on the transmitter [24].

4. MIMO system

When the CSI obtained on both the transmitter and receiver sides, it used a singular value Decomposition (SVD) for convert the channel of MIMO to the group of similar substitute-channels. Thus, a matrix of MIMO channel can be written as [25]:

$$H = U\Sigma V^H \quad (8)$$

Which Σ is $M_R * M_T$ is diagonal matrix (non-negative), U is $M_R * M_R$, V is $M_T * M_T$, are unitary matrices, separately. And, $UU^{Hl} = I_{MR,}$, and $VV^{Hl} = I_{MT,}$. Non-negative square roots of the eigenvalues are entries of $\boldsymbol{\Sigma}$for a channel matrix (HH^H). The entries of the eigenvalues are in descending order and positive numbers, such $\lambda_{i,} \geq \lambda_{i+1}$ [21].Via multiplied the inverse of U and V matrices in both a receiver side and the transmitter side correspondingly, interference with the channel can be converted to a set of singular value channels individually, and the relationship of input and output Adjust to [25]:

$$\tilde{y} = \sqrt{\frac{E_s}{M_T}}U^H HV\tilde{s} + U^H n = \sqrt{\frac{E_s}{M_T}}\Sigma\tilde{s} + \tilde{n} \quad (9)$$

Which $\tilde{y}$is received signal of converted vector for the size of $(r \times l)$,and $\tilde{n}$ is converted vector of AWGN with size of $(r \times l)$. The rank of Hmatrixis r, with the CSI at a transmitter side, *H matrix could obviously be disintegrated into, r SISO-channels sustaining [21]*.

$$\tilde{y}_i = \sqrt{\frac{E_s}{M_T}}\sqrt{\lambda_i}\tilde{s}_i + \tilde{n}_i\,,\ i = 1, 2,, r \quad (10)$$

5. Simulation Results and Discussion

Bit /second/Herts (b/s/Hz) are usually used to measure the capacity of a wireless link. Methods available to increase this capacity for a traditional SISO system are limited: increase the B_w, permitting a corresponding growth in the (b/s/Hz), or increases power transmions, permitting a higher level of modulation scheme to be utilized for specified bit error rate (BER), effectively increasing the (b/s/Hz) within same B_w. Problem with both of these methods in that increasing the consumed power or B_w may affect other systems working in close spectral channels or within a precise area. Regulating $B_{w,}$ and power for certain communications system will limiting its ability to support any increase in performance or capacity. Using Multi-antenna schemes may help in overcoming most of these traditional methods deficiencies. The algorithm SISO, MIMO, and other Multi-antenna (MISO, SIMO) schemes have similar steps of construction to be generated for channel capacity, Fig. (3). show this algorithm.

1) Simulation of SISO system: Fig. (4). Illustrate a capacity of SISO system over SNR, it can be seen that very slowly increasing in capacity with the SNR logarithm and it generally low. The SISO system capacity at SNR = 20 dB is about 6 b/s/Hz.

2) Simulation of SIMO system: Fig. (5). illustrates, the channel capacity of SIMO system, it can be seen that the SIMO system, at SNR, equal to 20 dB, has an enhancement of capacities for M_R = 2, 3 and 4, of about (7, 7.6, and 8) b/s/Hz, respectively. The highest capacity improvement for the SIMO system capability was achieved versus the SISO system was reached using (1 x 4) scheme, which is approximately to 2 b/s/Hz.

3) Simulation of MISO system: If CSI obtained, power divided among all antennas. Thus, improves the capacity of the MISO system against the SISO system, but with a small improvement. Except if the transmitter knows the CSI, the channel capacity of the MISO system will be enhanced. This is illustrated in Fig. (6). this can be seen in Fig. (6). The MISO system, if CSI can be obtained at the end of the transmitter, a greater improvement of capacity than SISO capacity of about 1.44, 1.72 b/s/Hz for MT = 2, 3 and 4 separately. Therefore, the maximum capacity of the MISO system versus the SISO system using a (1 × 4) scheme, which is approximately 1.72 bits.

4) Simulation of MIMO system: Channel capacity can be much better than previously tested systems. When CSI available at the transmitter. This is obviously shown in Fig. (7). the channel capacities of the MIMO system are about, (11.26, 16.69, and 22.14) b/s/Hz for (2×2), (3×3), and (4×4) schemes, correspondingly. The major enhancement in capacity versus SISO system by about 17 b/s/Hz for (4×4) scheme.

Input
No of antennas in the transmitter (M_T)
No of antennas in the receiver (M_R)
Number of transmitted bits (Ls)
SNR vector
Output
Capacity curve
Initialization
Set the vector of (SNR)
Set the Number of bits to be transmitted (L_S)
Set No antennas of transmitter and receiver (M_T, M_R)
Procedure
1. Begin
2. Generate channel model for (SISO, MISO, SIMO or MIMO)
3. Initializing counter i = 0, for SNR
4. For every SNR 5. compute a capacity C for (SISO, MISO, SIMO, MIMO) system using corresponding Eq.(2, 5, 7 and 9)
6. If counter i < max of SNR then 7. i=i+1 ; 8. return to step 3
9. Plotting curve of the capacity
End.

Fig. 3: The standard algorithm for single and multiple antennas on the receiver and receiver sides

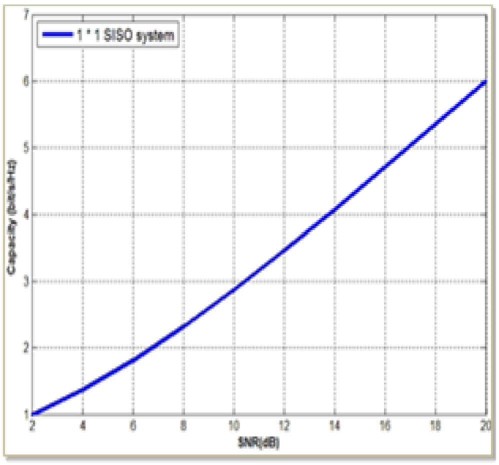

Fig. 4: Channel capacity of SISO

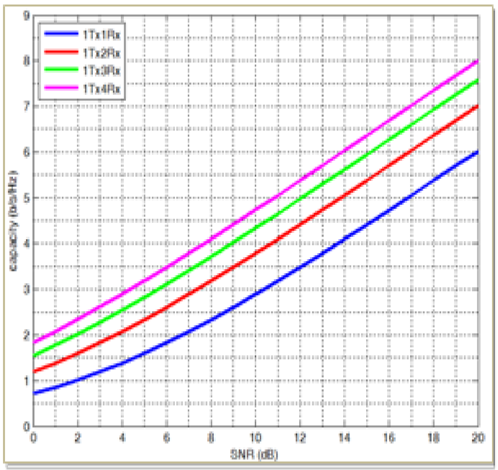

Fig. 5: Channel capacity of SIMO

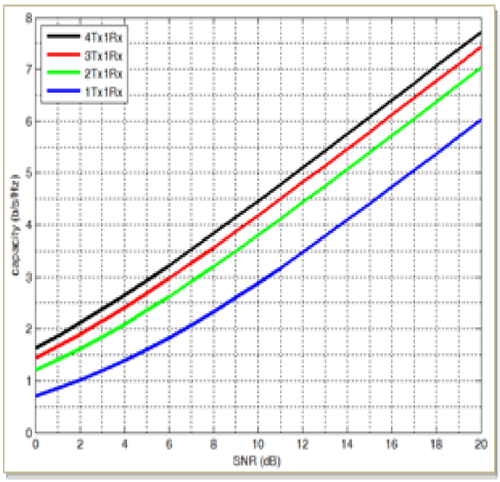

Fig. 6: Channel capacity of MISO

5) Comparison of the systems capacities

The comparison of the MIMO and the SIMO systems capacities are shown in Fig. (5) and Fig. (7), for (1×2) and (1×4) schemes with (2×2) and (4×4) schemes cases. From these Figures, It can be noted that there is a wide difference in capacity between MIMO and SIMO systems. The maximum capacity improvement of MIMO system using (4×4) scheme over SIMO using (1 x 4) scheme was reached at SNR = 20 dB. Which is 14.14 b/s/Hz. This can be seen in Fig. (8).

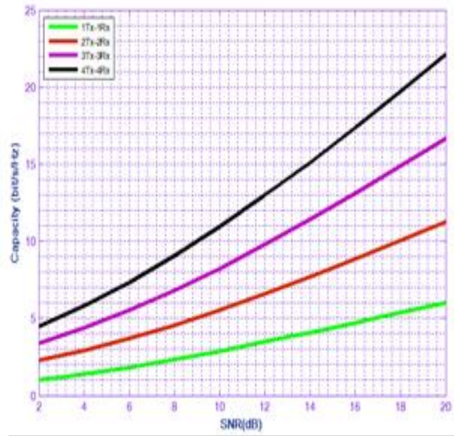

Fig. 7: MIMO system capacity with CSI at transmitter

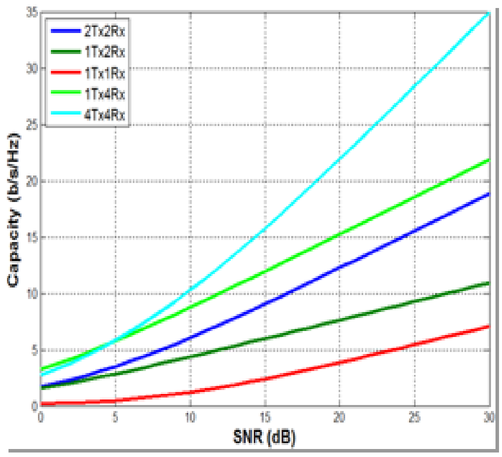

Fig. 8: MIMO and SIMO Channel Capacity Comparison

Table (1), offer capacities that achieved by using different systems, at SNR = 20 dB.Fig. (9). Clarify the results achieved to improve the data transfer rate in VANET channel capacity between MIMO technology and different systems.

Table 1: Achieved Capacities of SISO, SIMO, MISO and MIMO Systems

SYSTEM	STRUCTURE	B/S/HZ
SISO	1 * 1	6
MISO	2 * 1	7
	3 * 1	7.44
	4 * 1	7.72
SMO	1 * 2	7
	1 * 3	7.6
	1 * 4	8
MIMO	2 * 2	11.26
	3 * 3	16.69
	4 * 4	22.14

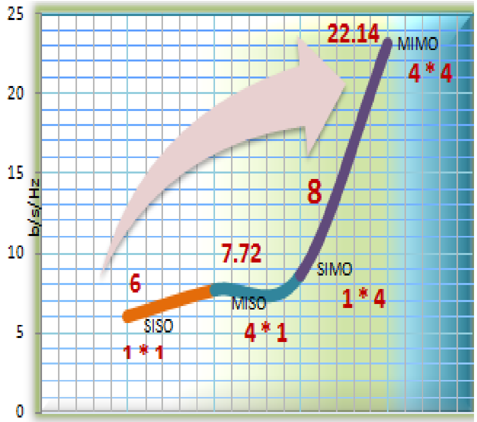

Fig. 9: Channel Capacity of (SISO, MISO, SIMO and MIMO)

6. Conclusion

Using MIMO technology in the vehicular communications takes numerous assistances that meet the main challenges and exploiting chances to exceed the complexity in processing the inter-vehicular communication scenarios and their future applications. These assistances comprise the communication range extending, rising the data rate, developing reliable and secure communication, and handling the interference that produced due to the multiusers. Another benefit is to configure the arrays of the transmission and/or reception based on the density of the used traffics (sparse scenarios vs. dense), adjacent broadcast environment (urban vs. rural) and most importantly the vehicular application of interest, in order to meet stringent safety requirements and deliver acceptable user experience for infotainment applications. The problem in SISO channel capacity of a wireless link, with that of any increase in B_w or power can harmfully disturb further systems working in neighboring channels or within a specific area. So, Using MIMO technologies overcome the deficiencies of the traditional method. Specifically, limited data rates. SM schemes utilize the spatial dimension in VANET environments to increase the link capacity without expanding the bandwidth. The spatial multiplexing gain is attained through conducting separate signals of data simultaneously on spatially (parallel data pipes) for an equivalent frequency.

Capacity of channel at SNR = 20 dB can be summarized as follows:

SISO system capacity is about 6 b/s/Hz.

The highest capacity improvement for the SIMO system using (1 x 4) scheme versus SISO was achieved by about to 2 b/s/Hz.

The highest capacity improvement for the SIMO system using (4 x 1) scheme versus SISO was achieved by about to 1.72 b/s/Hz.

The highest capacity improvement for the MIMO system using (4 x 4) scheme versus SISO was achieved by about to 16.14 b/s/Hz.

Future Work

The SIMO, MISO and MIMO systems could be used in combination to gain benefits accumulated by both, ultimately, the space time code schemes operative over combining with channel of MIMO, permits MIMO based system to support a major growth in both capacity and performance through a corresponding SISO whereas preserving a same power and bandwidth.

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