SOLUTIONS TO 6G WIRELESS ROADBLOCKS

Achieving the Ultimate Network Performance

David E. Newman and R. Kemp Massengill

Executive Summary

Major roadblocks need immediate attention for 6G to become a successful business reality. Developers are under great competitive pressure to deliver large improvements over 5G. And simply recycling 5G modalities will not be sufficient to achieve the desired success. Therefore, without new and truly creative innovative solutions, 6G faces serious shortfalls and unsatisfactory compromises that will negatively affect adoption and the hoped for increases in revenue.

Those roadblocks are:

(a) beam control to maintain focus on the intended recipient without wasting energy;
(b) inevitable increase in message faulting due to network crowding and attenuation;
(c) need for improved methods for high-throughput communications.

In this whitepaper, we offer winning solutions to these roadblocks. Each 6G solution can be implemented by allowing base stations and user devices to select the desired new procedures.

It is universally understood that time is of the essence for major business victories. We therefore recognize that developers should be made aware of creatively significant, practical solutions as soon as possible, and certainly before the next Standards Release is published.

Herein, we propose a mutually successful business outcome: UltraLogic6G seeks a 3GPP Member company to acquire our protected IP [1], incorporate it in the Standards, and enjoy substantial licensing revenue thereafter.

SECTION 1: PROPOSED STANDARDS FOR BEAM CONTROL

The conflicting goals of high throughput and low energy consumption present a real challenge for 6G. In this section, methods are outlined for improved beam alignment without beam scanning, improved power control without power scanning, and improved feedback at low cost.

Earliest Possible Disclosure of Base Station Location

Beamforming is essential for meeting the rising demand. Currently, beam alignment involves a tedious and energy-intensive beam scan procedure with multiple back-and-forth messages. We propose a simpler alignment method that enables the user to aim its beam toward the base station upon first contact.

Before making contact with the base station, new user devices receive a system information message (the SSB message) on the broadcast channel. We propose that the base station's location be added to the SSB message. A prospective user device can then read the location with the SSB message, calculate the angle relative to its own location, and align its beams immediately - without a beam scan.

In addition:

1. The user device can use its directed reception beam to receive other system information data, such as the SIB1 message, and other messages.

2. The user device can use a directed transmission beam to transmit the initial entry request (the random-access preamble), and other access messages, to the base station.

3. The user device can calculate the distance to the base station according to the location data, and thereby adjust its transmission power for proper reception, without a power scan.

Figure 1 shows how the modified SSB message would look to new user devices. The user device first synchronizes with the base station's clock using the PSS and SSS portions, and receives the BPCH data as usual. The user device then reads the location data from the fifth symbol-time, containing the latitude and longitude of the base station's antenna. The user device can then align its own beam toward the base station, without a beam scan, in time to receive the SIB1 message, thereby obtaining far greater signal clarity. Then, using the calculated power level and the calculated alignment angle, the user can transmit a random-access preamble to the base station, thereby initiating the process of joining the network.

By avoiding a beam scan and a power scan, the user saves time, resources, and energy. The cost is extremely low, just a single symbol-time added to the regular SSB message.

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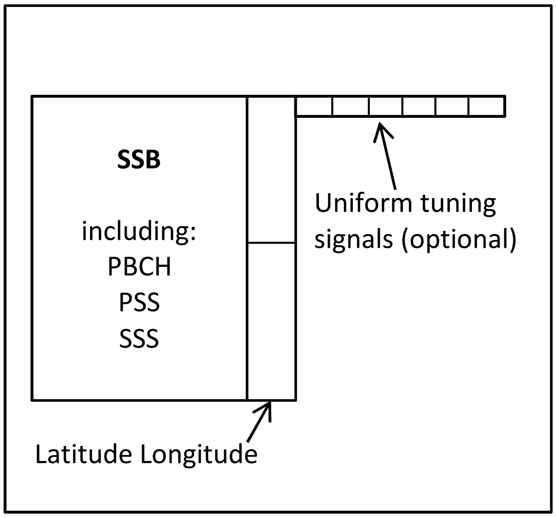

Fig. 1: The first system information message (SSB), followed by the latitude and longitude of the base station's antenna, and a series of uniform tuning signals.

The figure also shows a string of "uniform tuning signals" after the location data. These are unmodulated signals, all the same, that the user can use to fine-tune its reception beam, if desired.

The user device can also inform the base station of its location early in the initial access procedure. For example, the user can append its location data to the Msg3 of a four-step access procedure, or the MsgA of a two-step procedure, or in a subsequent message. The base station could then begin using directed beams and appropriate power for subsequent communications with the user device. A 3GPP Member company can add these valuable features to the 6G standards. UltraLogic6G is prepared to assist that Member company in doing so.

Angle-Dependent Alignment Pulse

An entirely different beam alignment option is shown in Figure 2 below. Here the base station transmits an "angle-dependent alignment pulse", which is a single pulse tailored to have a different phase in each direction all around the base station. A user device can determine its alignment angle by detecting the pulse and measuring the phase. All of the user devices can align their beams simultaneously, with just one pulse from the base station.

The angle-dependent alignment pulse has many advantages. It enables simultaneous alignment of all the users at low cost. It eliminates the time-consuming and energy-consuming beam scan for each user device. And it is easy – every wireless user device can measure the phase of a pulse.

The base station can also transmit a "calibration" pulse, which has the same phase all around. User devices can compare the two pulses and get better accuracy.

The base station can also transmit a "vernier" pulse with a much higher phase gradient, such as varying a full 360 degrees in phase for just 90 degrees in angle. This enables the users to determine their alignment angle with better precision.

The user device can then inform the base station of the alignment angle, so both entities can use directed beams.

We propose that a 3GPP Member company add the angle-dependent alignment pulse as an option to the 6G standards. This will enable fast and easy beam alignment without a beam scan, saving substantial energy and avoiding background generation.

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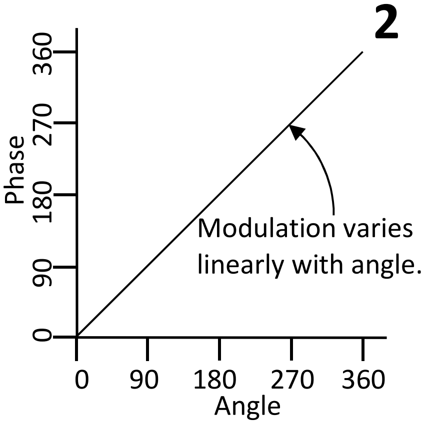

Fig. 2: Base station transmits a single pulse modulated to have a different phase (or amplitude) at each angle.

Network Database

Mobile users often search for a nearby base station to log in to. The current procedure requires a complex series of steps, with uncertain outcome.

Instead, we propose a "network database", which is a file containing the locations and broadcast frequencies of all base stations in a region. The user device can then check the network database to find the closest available base station. This avoids a large number of complex tasks for user devices.

In addition, the network database can also include all the system information and settings from the system information messages, such as the SSB and SIB1 messages. The user then adjusts its settings accordingly, and transmits the initial access request without further delay.

In addition, the user device can calculate the distance, and thereby set the power of the initial access request appropriately, without a power scan.

The user device can acquire the network database file by any number of ways. It could download the file at an earlier time, such as before starting the trip, or the file could be installed in the user device upon manufacture, and then updated whenever connected.

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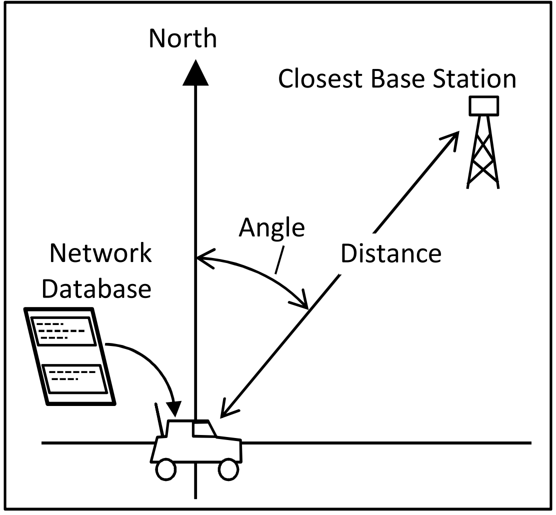


Fig. 3: A mobile device uses its internal Network Database file to find the nearest base station and its broadcast frequency. User then aligns its reception beam toward the antenna, receives system info messages, adjusts its power according to the distance, and transmits an initial access request.

We propose that a 3GPP Member company write an option into the 6G standards for such a network database. This will help user devices access base stations more easily, enable selection of the most appropriate one before communicating, and will save both time and energy.

SECTION 2: PROPOSED STANDARDS FOR FAULT MITIGATION

Solutions for reducing message faulting at high frequencies are presented in this section. Message faulting in 6G is a serious limitation, especially at high frequencies. We propose a versatile modulation scheme with wider phase margins and the versatility needed to optimize reception.

Amplitude-Phase Modulation and Phase Noise Mitigation

Most data messages are modulated in QAM (quadrature amplitude modulation) in which the signal is composed of two orthogonal "branches" termed I and Q. Receivers naturally process the received signal in orthogonal components, so 6G uses QAM as a default.

Figure 4 shows a constellation chart for 16QAM. The dots are states of the modulation scheme, and the gray blobs represent the expected phase noise at the frequencies of 6G.

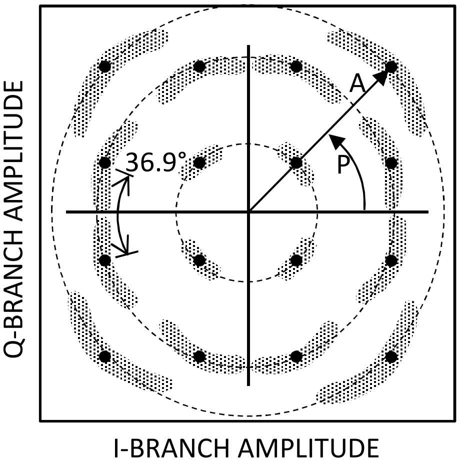
The amplitude (A) and phase (P) of the overall waveform are also indicated. It is easy to calculate A and P from I and Q, and vice versa.

Some of the states are so close together, the phase noise distributions almost overlap, and this causes message faults. The minimum phase separation of 36.9 degrees is far too small for 6G. This is the source of most phase noise faulting in 6G.

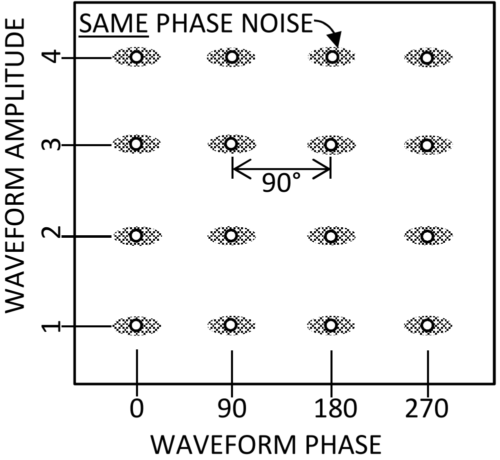
Dotted circles also indicate the waveform amplitudes of the states. Although the branches are modulated in four amplitude levels, there are actually only three waveform amplitudes in 16QAM, as you can see. This limits the information density available for data.

To solve the problem of message faulting, we propose an alternative modulation scheme, "amplitude-phase modulation" in which the amplitude and phase of the overall waveform are modulated according to the message data. Figure 5 is a chart of its states. There are 16 states, same as 16QAM, but they are more widely spaced apart.

16QAM modulation **4**



amplitude-phase modulation **5**



In fact, every state has a full 90 degrees of phase margin. This greatly reduces message faulting. The gray blobs in Figure 5 represent EXACTLY THE SAME PHASE NOISE as in Figure 4. They look smaller because the phase margins are much larger in amplitude-phase modulation. Consequently, phase faulting will be much less problematic in 6G if we use amplitude-phase modulation instead of QAM.

Also note that in Figure 5 there are four amplitude levels instead of three, and they are equally spaced. Therefore, amplitude-phase modulation makes maximum use of the available modulation space for information encoding, leading to higher throughput than QAM.

It is easy to implement amplitude-phase modulation with regular hardware and signal processing. The receiver calculates the waveform A and P values from the I and Q branch values, and demodulates with A and P. No changes are needed in the transmitter or receiver hardware.

More specifically: The transmitter modulates the message using amplitude-phase modulation and transmits it. The receiver receives it and separates it into I and Q branches as usual, and measures the branch amplitudes as usual. Then, the receiver calculates the waveform amplitude and waveform phase as follows: $A=\surd(I^2+Q^2)$ and $P=\arctan(Q/I)$. The receiver then demodulates in A and P, same as the transmitter. And that's all there is to it! Amplitude-phase modulation provides wider phase margins and higher information content in 6G messages, at zero cost.

We propose that a 3GPP Member company include, as an option, amplitude-phase modulation in 6G, especially at high frequencies where phase faulting is otherwise a limiting factor.

Asymmetric Modulation

Another big advantage of amplitude-phase modulation is that it enables asymmetric modulation, in which the number of amplitude levels is different from the number of phase levels. This allows the base station to select a modulation scheme specifically optimized to combat the current noise environment.

For example, in Figure 6 there are 8 amplitude levels and 2 phase levels, 16 states each with a full 180 degrees of phase margin. This would be ideal at high frequencies where phase noise is a problem. At low frequencies where amplitude faults prevail, the network could use asymmetric modulation with more phase levels and fewer, spread-apart amplitude levels.

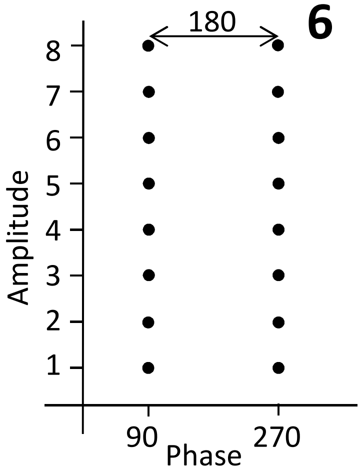


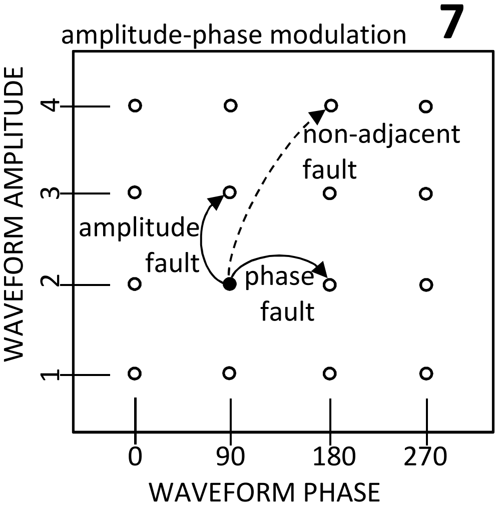
Fig. 6: Asymmetric modulation. Namp=8, Nphase=2, Nstates=16

Asymmetric modulation is a valuable feature because it enables the base station to shape the modulation scheme to mitigate current noise. QAM has no such capability because the I and Q branches are logically equivalent.

Fault Type Analysis

Another big advantage of amplitude-phase modulation is that message faults can be specifically diagnosed as due to phase noise or amplitude interference, or some other cause.

Figure 7 shows the difference. The black dot is the transmitted state. A phase fault is a distortion of one phase level, and an amplitude fault is a distortion of one amplitude level. A non-adjacent fault is off by multiple A and P levels.



Each type of faulting requires a different type of mitigation strategy. By determining the current fault types, the base station can intelligently select a better modulation scheme.

Fault-type analysis is not possible in QAM because noise scrambles the I and Q branches. This conceals the source of the problem. Hence in QAM, faults are just faults.

Due to the many advantages of amplitude-phase modulation, and the zero cost of using it, we propose that a 3GPP Member company present this option in the next standards Release.

SECTION 3: PROPOSED STANDARDS FOR NETWORKING

In this section, multiple innovations are disclosed enabling networks to save time and energy while achieving higher message reliability and higher throughput in 6G.

Demarcations to Identify Downlink Messages

For battery-constrained users, a major hurdle is simply recognizing their downlink control messages DCI). The user does not know when they will occur, nor the frequency, nor the length. So the user has to check every possible combination, and must do so rapidly during a single symbol-time of transmission to keep from missing its messages. This is a monumental task.

Another problem is that the user's identification is scrambled with the embedded error-detection code. This forces the user to demodulate and decrypt and unscramble each one of those myriad combinations of time, frequency, and length. Low-cost processors cannot possibly keep up.

A third problem is that scrambling the ID makes it impossible for users to correct a faulted message, or even to recognize a faulted message as being intended for that user. As a result, a lot of retransmissions are requested until a perfect version is finally received.

Networks have tried to solve this by restricting user messages to certain "search spaces". This provides only minimal relief, while increasing latency.

Figure 8 shows a low-cost solution. The base station can "demark" each downlink control message with easily-recognized signals. In this case, the demarcation is a blank resource element with no transmission in it. The user device can easily recognize the blanks, thereby extracting each message without searching. This alone would greatly reduce the user's computation burden.

In addition, the user's identification can be provided in an encrypted form for privacy, but NOT scrambled with the error-detection code, as shown in the figure. This would assist the user even further in recognizing its messages. It would also enable the user device to correct faulted messages, which is otherwise not possible.

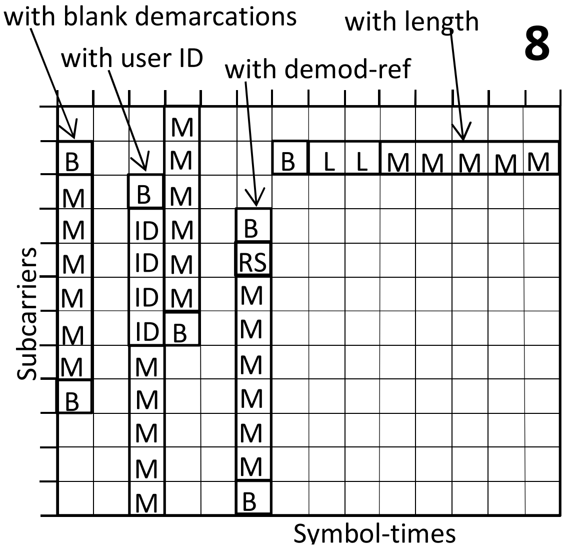


Fig. 8: DCI messages (M) can be demarked by a blank (B) resource element at start and end. They can also include the recipient's identification (ID), a demodulation reference signal (RS), and the message overall length (LL), to assist the user device.

As a further option, the network could demark the user's data messages as well as the control messages. In that case, the user can easily find its data messages. The user no longer needs DCI messages (for downlink scheduling only), and the network can stop transmitting them. This would result in lower latency, lower energy consumption, lower background generation, and vastly simpler reception for user devices.

Therefore, we propose that a 3GPP Member company add the option of demarking downlink control and/or data messages with a recognizable signal (such as blank), and also that the user ID not be masked by the error-detection code.

Temporary QoS Elevation

Message priority is determined by the QoS (quality of service) requested by the user. Emergency responders request high QoS for priority communication, whereas a simple temperature sensor would use a low QoS to save money.

However, there are times when a high-QoS user wishes to transmit a low-priority message such as a routine confirmation. There are also times when a low-QoS user suddenly needs fast service, for example the temperature sensor reporting a fire. Currently, users can only change their default QoS. Transmitting a single message with a different priority involves multiple steps, and changing back requires more messages, a costly delay.

What's needed is a "temporary QoS" option in which the user device can specify an increase or decrease in the QoS handling of a single message, without changing the default. For example, the user device can append a brief code to its scheduling request or its BSR (size) message, indicating whether a temporary increase or decrease in QoS is needed.

Therefore, we propose that a 3GPP Member company should add an option in 6G (or sooner) enabling user devices to request a QoS elevation or reduction for a single uplink message. Users will appreciate the added flexibility.

Short-Form Demodulation Reference

A demodulation reference is a short transmission indicating the amplitude or phase modulation levels of the current modulation scheme. The receiver can then compare the modulation levels of a message with those of the demodulation reference, and thereby negate the effects of noise (assuming the demodulation reference is close enough to the message).

Currently, demodulation reference signals are multi-symbol constructs encoding various information other than the predetermined modulation levels.

Therefore, we propose a shorter, simpler, non-encoded "short-form" demodulation reference that exhibits a subset of the modulation levels, but enough that the receiver can easily fill in the missing levels by interpolation. Such a brief signal can be placed in closer proximity to the message, and even embedded within the message, thereby providing highly localized noise cancellation.

An advantage of short-form demodulation references is that they are small enough to be added to each message at negligible cost. For additive noise (which most wireless noise is), it is sufficient to specify just one or two levels, such as the maximum and minimum amplitudes, and the receiver can calculate the rest.

Therefore, we propose that a 3GPP Member company add short-form demodulation references as an option to the 6G standards, to provide an extremely granular noise cancellation option.

Guard-Space Demodulation Reference

As an alternative demodulation reference option, the guard-space between message elements could be re-purposed as a demodulation reference. This would provide a fresh calibration in each symbol-time of the message. The guard-space is a short region just before the message data, and serves to keep the symbols separate. Currently, the last portion of the message data of each message element is copied into the guard-space, but this is not absolutely required.

Instead, we propose that a demodulation reference be placed in the guard-space of an OFDM symbol. The OFDM symbol is a sum of hundreds of subcarrier signals, and has a much larger bandwidth. The guard-space demodulation reference could then provide local noise cancellation at no cost in terms of resource area, transmitted power, and energy consumed.

Therefore, we propose that a 3GPP Member company promote an option of putting a short-form demodulation reference in each guard-space of each message, for enhanced noise cancellation.

Zero-Power States

The high throughput goal of 6G requires packing as much information into each message element as possible. Currently, the modulation schemes planned for 6G include QPSK and various orders of QAM.

We propose to extend these with new modulation states, termed "zero-power" states, which the receiver can easily and unambiguously recognize.

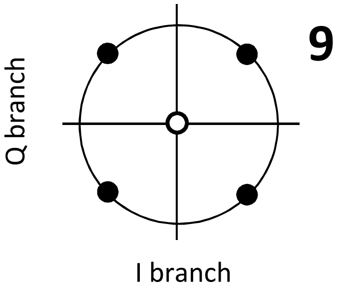


Fig. 9: A fifth zero-power state in QPSK is easily discriminated, and results in higher throughput.

Figure 9 shows the four states of QPSK as dots. They are equally-spaced phases at constant amplitude. The new state (circle at the center) has zero power transmitted, that is, a blank message element. The fifth state enables shorter messages due to the higher information content.

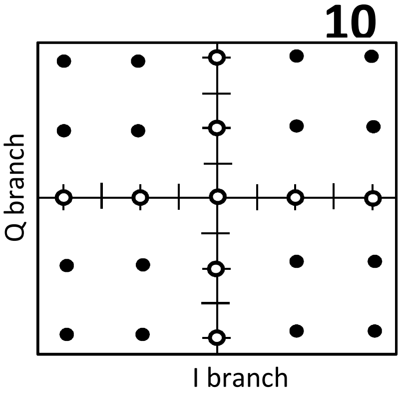


Fig. 10: 16QAM has 16 states in I and Q branches. Here 9 additional states are added, having zero power in one or both branches.

Figure 10 shows 16QAM, slightly adjusted, plus eight new states in which one of the I or Q branches has zero power, and a central new state with zero power in both branches, that is, nine new states in total.

In these and other cases, the information density is increased with zero-power modulation states, resulting in shorter messages and hence higher throughput, at no cost.

As an option, one of the zero-power states could be reserved for special functions, such as demarking the start and end of messages (as mentioned), among many other possible uses.

Therefore, we propose that a 3GPP Member company should introduce modulation schemes including zero-power states as an option in 6G, for higher throughput and thus lower transmission energy expended.

Synchronization and Timing

High-speed wireless is critically dependent on precise time synchronization between the transmitting and receiving entities. Any deviation results in message faults, among other problems.

Currently, each wireless user is expected to synchronize with the base station using a time-consuming, message-heavy legacy procedure.

Therefore, we propose a simpler, low-complexity synchronization procedure sufficient to enable proper uplink and downlink communication with a base station. Specifically, the new procedure enables the user device to (a) adjust its clock rate to match the base station including a Doppler shift if any, (b) determine an arrival time of downlink messages accurate to a fraction of a symbol-time including the one-way propagation time, and (c) determine a timing advance sufficient to cause its uplink messages to arrive at the base station aligned with the base station's resource grid, including the one-way propagation time (Figure 11).

The new procedure satisfies all those requirements, is quite simple, and occupies just a few resource elements.

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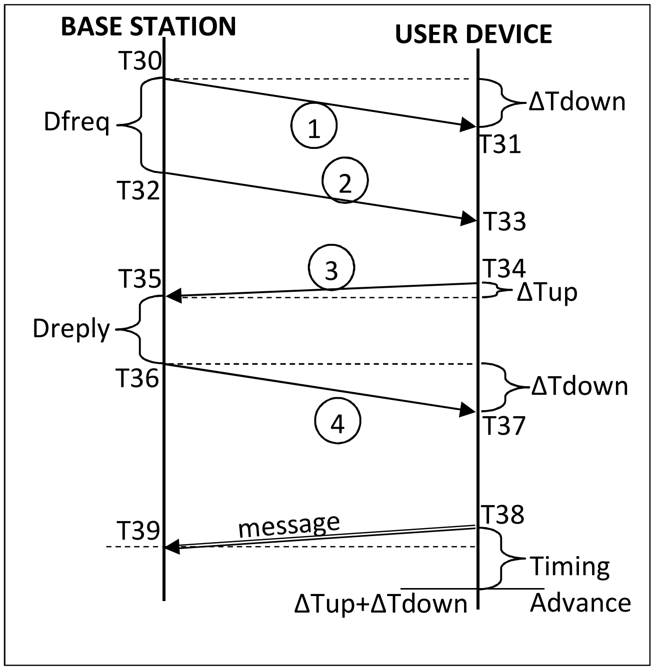

Fig. 11: Base station aligns user device using only 4 transmissions at scheduled times.

First, the base station sends out two signals (1,2). Each is a single-resource-element pulse at a predetermined time and frequency. The user device receives those two pulses and adjusts its clock setting according to the scheduled transmission time (T30) of the first pulse, and then adjusts its reception clock rate according to the predetermined interval between the two pulses (T32-T30), thereby matching the base station's clock rate. Then the user device transmits a third pulse (3), uplink, again occupying a single resource element at a predetermined time according to the user's now-corrected clock. The base station receives the third pulse and, after a predetermined delay (T36-T35), transmits a fourth pulse (4) back to the user. The user then subtracts the predetermined delay from the time interval between sending the third pulse and receiving the fourth pulse (T37-T34), and uses that remainder as the timing advance, relative to the user's resource clock, for transmitting uplink messages.

With this simple and economical procedure, the user device has matched the base station clock, arranged to receive downlink messages aligned with its reception clock, and arranged to set the timing advance of its transmission clock so that uplink messages will arrive correctly timed with the base station's resource grid, thereby fulfilling all of the requirements, with just four brief pulses.

If the user device is in motion, the same procedure can be used to account for the Doppler shift as well. The absolute time, according to the base station, can also be calculated by subtraction.

Therefore, we propose that a 3GPP Member company should add the simplified synchronization procedure as an option for user devices in 6G standards.

Conclusions

The current 6G plans continue to require legacy procedures that often are costly in terms of time, resource area, and energy consumption, as well as being overly complex. In this paper, we have outlined numerous solutions for providing faster, simpler, cheaper procedures that accomplish the same objectives while conserving resources and avoiding annoying the user.

The solutions mitigate important problems for high-performance wireless. **Beam control** is central to delivering sufficient signal to the intended recipient; **fault mitigation** is crucial for maintaining the high reliability and low latency promised; and **communication enhancements related to access, synchronization, and modulation** will provide significant gains in throughput and reliability.

UltraLogic6G is deeply committed to making 6G successful. Therefore, we submit that one of the 3GPP Member companies should advance this project forward by introducing the compelling solutions herein to peer Members – and placing these game-winning advances as options in the coming 6G Standards. The revenue generated for the Member company, by licensing these solutions to other developers and providers, will far exceed the expense.

Wireless companies recognizing this opportunity are encouraged to contact us at:

Kemp Massengill
760-390-1410 (PT)
kemp.massengill@UltraLogic6G.com

Glossary

"Base station", as used herein, includes all network assets communicating with users, including access points, access relay stations, roadside monitors, satellite relays, and the like. The term also includes the core network, backhaul, and other internal systems of the network assets, unless otherwise called out.

"User device", as used herein, refers to the radio portion of user equipment, specifically the transmitter, receiver, antenna, signal processing electronics, and demodulation processor. The term also includes AI models for fault mitigation and message interpretation and the like, when present.

3GPP (Third Generation Partnership Program) is the primary organization for wireless technical specifications, and with seven "Partner" organizations, promulgates universal wireless standards.

OFDM (Orthogonal Frequency-Division Multiplexing) means transmitting message data in multiple frequencies (subcarriers) at the same time. The receiver then measures the subcarrier signals to separate and demodulate the message elements.

IoT (Internet of Things) devices are low-cost, reduced-capability wireless sensors and actuators.

SNR (Signal-to-Noise Ratio), as used herein, includes interference, stochastic noise, clock drift, and all other effects causing message faults, unless specifically indicated.

FR1 and FR2 are frequency ranges. FR1 is 7.125 GHz and below (and up to 8.4 GHz in 6G). FR2 is 24.25 GHz and up. FR2 is often called mmWave, although a wavelength of 1 mm actually corresponds to a frequency of 300 GHz.

QPSK (quadrature phase-shift keying) is phase modulation at constant amplitude with 4 states separated by 90 degrees, carrying 2 bits per symbol

QAM (Quadrature Amplitude Modulation) is a modulation scheme in which the message data is encoded in the amplitudes of two orthogonal signal components, termed I and Q branches.

A resource grid is an array of resource elements, arranged by symbol-times in time and subcarriers in frequency.

A message element is a single modulated resource element of a wireless message.

A "symbol-time" is the time duration of a single message element.

References

[1] The following patents detail the solutions presented above, and can be found at: www.UltraLogic6G.com.

US Patent	Title
11,153,780	Selecting a Modulation Table to Mitigate 5G Message Faults
11,202,198	Managed Database of Recipient Addresses for Fast 5G Message Delivery
11,206,092	Artificial Intelligence for Predicting 5G Network Performance
11,206,169	Asymmetric Modulation for High-Reliability 5G Communications
11,297,643	Temporary QoS Elevation for High-Priority 5G Messages
11,387,960	Downlink Demarcations for Rapid, Reliable 5G/6G Messaging
11,387,961	Short-Form Demodulation Reference for Improved Reception in 5G and 6G
11,398,876	Error Detection and Correction in 5G/6G Pulse-Amplitude Modulation
11,411,795	Artificial-Intelligence Error Mitigation in 5G/6G Messaging
11,418,372	Low-Complexity Demodulation of 5G and 6G Messages
11,438,834	Searchable Database of 5G/6G Network Access Information
11,451,429	Modulation Including Zero-Power States in 5G and 6G
11,502,893	Short-Form 5G/6G Pulse-Amplitude Demodulation References
11,509,381	Resource-Efficient Beam Selection in 5G and 6G
11,510,096	Selecting a Modulation Table to Mitigate 5G Message Faults
11,516,065	Identifying Specific Faults in 5G/6G Messages by Modulation Quality
11,522,745	Identification and Mitigation of Message Faults in 5G and 6G Communications
11,523,334	Network Database for Rapid, Low-Complexity 5G/6G Network Access
11,528,178	Zero-Power Modulation for Resource-Efficient 5G/6G Messaging
11,546,111	Demarking the Start and End of 5G/6G Downlink Messages
11,558,236	Single-Branch Reference for High-Frequency Phase Tracking in 5G and 6G
11,601,150	Demodulation for Phase-Noise Mitigation in 5G and 6G
11,601,320	Single-Point Demodulation Reference for Noise Mitigation in 5G and 6G
11,616,668	Fault-Tolerant Method for Demodulating 5G or 6G Messages
11,616,679	Detection and Mitigation of 5G/6G Message Faults
11,626,955	Resource-Efficient Demodulation Reference for 5G/6G Networking
11,637,649	Phase-Noise Mitigation at High Frequencies in 5G and 6G
11,644,522	Triangular Beam Configurations for Rapid Beam Alignment in 5G and 6G
11,652,533	Rapid Alignment of User Directional Beams in 5G/6G Networks
11,671,305	Extremely Compact Phase-Tracking 5G/6G Reference Signal
11,695,612	Method to Locate Faulted Message Elements Using AI in 5G and 6G
11,722,980	Guard-Space Timestamp Point for Precision Synchronization in 5G and 6G
11,736,320	Multiplexed Amplitude-Phase Modulation for 5G/6G Noise Mitigation
11,736,333	Information Content in Zero-Power Modulation States in 5G and 6G
11,737,044	Mid-Symbol Timestamp Point for Precision Synchronization in 5G and 6G
11,777,547	Phase-Tracking Demodulation Reference and Procedure for 5G and 6G
11,777,639	How to Maximize Phase-Noise Margins in 5G and 6G
11,782,119	Phased Beam-Alignment Pulse for Rapid Localization in 5G and 6G
11,799,608	Low-Complexity Method for Identifying Downlink Messages in 5G and 6G
11,799,707	Guard-Space Phase-Tracking Reference Signal for 5G and 6G Networking
11,800,480	Ultra-Lean Timing Signal for Precision Synchronization in 5G and 6G
11,805,491	Compact Timing Signal for Low-Complexity 5G/6G Synchronization
11,811,565	Demodulation Using Two Modulation Schemes in 5G and 6G
11,824,667	Waveform Indicators for Fault Localization in 5G and 6G Messages
11,832,128	Fault Detection and Mitigation Based on Fault Types in 5G/6G

11,832,204	Ultra-Lean Synchronization Procedure for 5G and 6G Networking
11,843,468	Fault Detection, Localization, and Correction by 5G/6G Signal Quality
11,943,160	Resource-Efficient Demarcations for Downlink Messages in 5G and 6G
11,950,197	Precision Timing for Low-Complexity User Devices in 5G/6G Networks
11,956,746	Precision Synchronization Using Amplitude Measurements in 5G and 6G
11,996,971	Enhanced Throughput and Reliability with Zero-Power States in 5G and 6G
11,996,973	Scheduling Single-Branch Phase-Tracking References in 5G and 6G
12,034,571	Modulation and Demodulation for Enhanced Noise Margins in 5G and 6G
12,038,519	Low-Complexity Beam Alignment by Directional Phase in 5G and 6G
12,040,891	How to Maximize Throughput and Phase Margin in 5G/6G Communications
12,047,219	Fault Detection and Correction by Sum-Signal Modulation in 5G or 6G
12,047,894	Rapid Low-Complexity Synchronization and Doppler Correction in 5G/6G
12,052,129	Ultra-Compact Phase-Tracking Demodulation Reference for 5G/6G
12,074,741	Identifying Faulted Message Elements by Modulation Consistency in 5G/6G

2023/0231685	AI-Assisted Selection of Demodulation Reference Type in 5G and 6G
2023/0246699	Low-Complexity Procedure for 5G/6G Beam Alignment
2023/0254198	Low-Complexity Resource-Efficient Demodulation Reference for 5G and 6G
2023/0262595	Automatic Base Station Discovery, Selection, and Registration in 5G/6G
2023/0300017	AI-Based Correction of Corrupted 5G/6G Messages
2023/0362720	Artificial Intelligence for Optimizing 5G/6G Wireless Network Performance
2023/0387952	Selecting a Modulation Scheme to Mitigate Specific Fault Types in 5G and 6G
2024/0045013	Deterministic Low-Complexity Beam Alignment for 5G and 6G Users
2024/0048429	Procedures for Efficiently Defaulting QAM Messages in 5G and 6G
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2024/0080144	Enhanced Reliability by Waveform Analysis in 5G/6G Communications
2024/0080231	Noise Mitigation by Guard-Space Reference Calibration in 5G and 6G
2024/0196354	Phase-Shift Guard-Space Timestamp Point for 5G/6G Synchronization
2024/0205857	Fast, Resource-Efficient Timestamp Generation and Measurement in 5G/6G
2024/0214961	Simultaneous Timing Synchronization of User Devices in a 5G/6G Wireless Network