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**Certified Wireless Network Administrator (CWNA)**
**PW0-106**

Chapter 19
Very High Throughput
(VHT) and 802.11ac

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## Chapter 19 Overview

- 802.11ac-2013 amendment
- 5 GHz only
- 20, 40, 80, and 160 MHz channels
- 256-QAM modulation
- Modulation and coding schemes
- Single-user MIMO

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## Chapter 19 Overview

- 802.11ac data rates
- VHT MAC
- Beamforming
- Infrastructure requirements
- 802.11ac in a SOHO or home
- Wi-Fi Alliance certification



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## 802.11ac-2013 Amendment

- Introduces Very High Throughput (VHT) technology with maximum transmission speed of 6.933 Gbps.
- Will be implemented in multiple phases
- Some of the features or capabilities may not exist yet in live product.

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## Comparison of 802.11n and 802.11ac

| Technology | 802.11n | 802.11ac |
|---|---|---|
| Frequency | 2.4 GHz and 5 GHz | 5 GHz only |
| Modulation | BPSK, QPSK, 16-QAM, 64-QAM | BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM |
| Channel widths | 20 MHz, 40 MHz | 20 MHz, 40 MHz, 80 MHz, 160 MHz |
| Spatial streams | Up to four | Up to eight on APs, up to four on clients |
| Short Guard Interval Support | Yes | Yes |
| Beamforming | Multiple types, both implicit and explicit, not typically implemented | Explicit beamforming with null data packets (NDPs) |
| Number of modulation and coding schemes (MCSs) | 77 | 10 |
| Support for A-MSDU and A-MPDU | Yes | Yes, all frames transmitted as A-MPDU |
| MIMO support | Single-user MIMO | Single-user MIMO and multiuser MIMO (MU-MIMO) |
| Maximum # of simultaneous user transmissions | One | Four |
| Maximum data rate | 600 Mbps | 6.933 Gbps |



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## 5 GHz Only

- In order to benefit from the faster data rates of 802.11n, companies have migrated to 5 GHz radios
- However, support for 2.4 GHz radios in older devices is still needed.
- Accomplished with dual-radio access points
- 802.11ac is designed to operate only in the 5 GHz band where much more frequency space is available.

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## 20, 40, 80, and 160 MHz Channels

- 802.11ac introduced two new channel widths: 80 MHz and 160 MHz
- The two 40 MHz channels that make up the 80 MHz channel must be adjacent.
- New 80 MHz channel consists of 242 subcarriers, of which 234 are used to transmit data, and 8 are used as pilot carriers
- 160 MHz channel is made up of two 80 MHz channels; however, the two 80 MHz channels do not have to be adjacent.
- 160 MHz channel consists of 484 subcarriers, with 468 used to transmit data, and 16 used as pilot carriers



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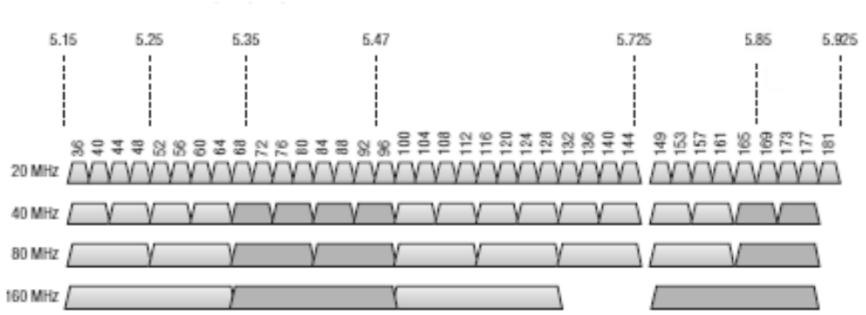
## 20, 40, 80, and 160 MHz Channels



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## Dynamic bandwidth operation

- 802.11ac feature that allows the AP to choose the channel width on a per-frame basis
- AP, operating at 80 MHz on channels 36, 40, 44, and 48, wants to transmit, it must first check to see if all four channels are available
- If one of the channels, such as 36, is currently being used, AP can transmit using a 40 MHz transmission on channels 44 and 48
- Allows 802.11ac devices to adapt to the environment while transmitting on the widest available channel.
- Channel selection for a single radio can require the selection of up to four channel groupings.
- Becomes much more difficult and important when choosing channels for multiple APs



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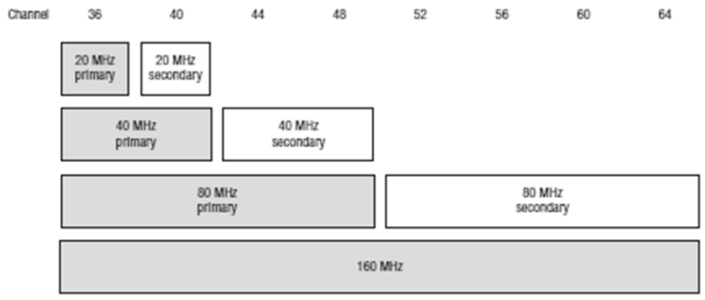
## Single AP 160 MHz channel plan



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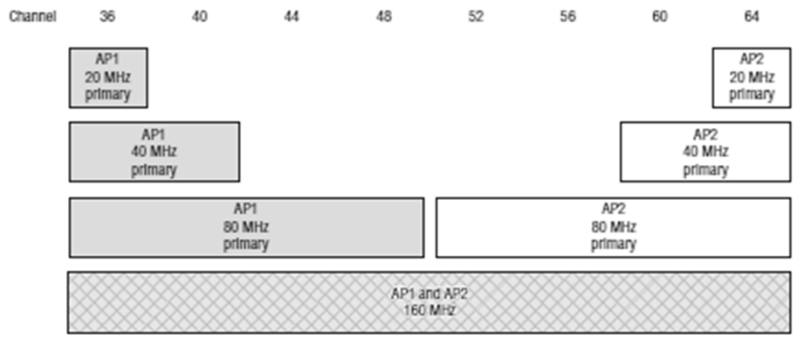
## Two APs, 160 MHz channel plan



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## 256-QAM Modulation

- Introduced with the 802.11ac amendment
- Identifies 256 unique values, using 16 different levels of phase shift and 16 different levels of amplitude shift
- For comparison , 64-QAM identifies 64 unique values and using eight different levels of phase shift and eight different levels of amplitude shift
- 256-QAM is more sensitive to noise and interference.
- 802.11ac receiver performance requires about 5 dB of additional gain as compared to 64-QAM.

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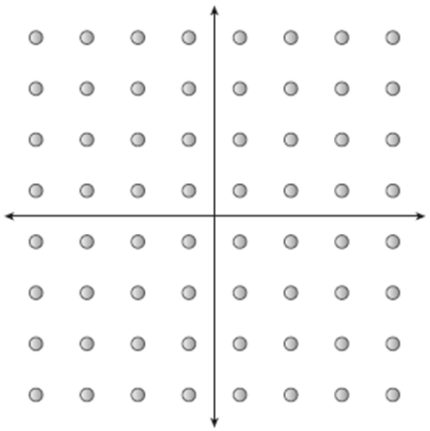
## 64-QAM constellation chart





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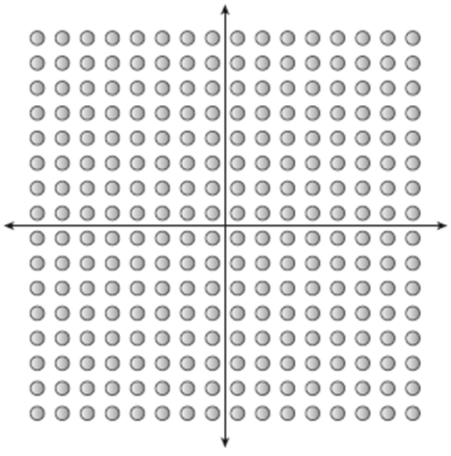
## 256-QAM constellation chart



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## Modulation and Coding Schemes

- 802.11n (HT) defined 77 different modulation and coding schemes
- 802.11ac simplified this by defining only 10 MCS options
- The first eight modulation and coding schemes are mandatory; however, most vendors will support the last two, which provide 256-QAM modulation



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## 802.11ac Modulation and Coding Schemes

| VHT MCS value | Modulation | Code rate (R) | 20 MHz data rate (Mbps) |
|---|---|---|---|
| 0 | BPSK | 1/2 | 7.2 |
| 1 | QPSK | 1/2 | 14.4 |
| 2 | QPSK | 3/4 | 21.7 |
| 3 | 16-QAM | 1/2 | 28.9 |
| 4 | 16-QAM | 3/4 | 43.3 |
| 5 | 64-QAM | 2/3 | 57.8 |
| 6 | 64-QAM | 3/4 | 65.0 |
| 7 | 64-QAM | 5/6 | 72.2 |
| 8 | 256-QAM | 3/4 | 86.7 |
| 9 | 256-QAM | 5/6 | 96.3* |

*MCS 9 is not supported for 20 MHz channels, only 40 MHz, 80 MHz, and 160 MHz.

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## MIMO types

- 802.11n uses single-user MIMO (SU-MIMO)
- 802.11ac, a new form of MIMO was introduced: multi-user MIMO (MU-MIMO)
- 802.11n amendment allows up to four spatial streams of data to be transmitted, most 802.11 n APs support 3
- 802.11ac amendment doubles the total number of supported spatial streams to eight
- 802.11ac access point chipsets that are expected to support MU-MIMO will most likely be 4 × 4:4 radios



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## 802.11ac Data Rates factors

| MCS | 20 MHz data rate | Spatial stream multiplier | Channel width multiplier |
|---|---|---|---|
| 0 | 7.2 | × 1 (1 streams) | × 1.0 (20 MHz) |
| 1 | 14.4 | × 2 (2 streams) | × 2.1 (40 MHz) |
| 2 | 21.7 | × 3 (3 streams) | × 4.5 (80 MHz) |
| 3 | 28.9 | × 4 (4 streams) | × 9.0 (160 MHz) |
| 4 | 43.3 | × 5 (5 streams) | |
| 5 | 57.8 | × 6 (6 streams) | |
| 6 | 65.0 | × 7 (7 streams) | |
| 7 | 72.2 | × 8 (8 streams) | |
| 8 | 86.7 | | |
| 9* | 96.3 | | |

*MCS 9 is not supported for 20 MHz channels, only 40, 80, and 160.

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## VHT MAC

- 802.11a, 802.11n and 802.11ac radios all use the same preamble and can calculate how long to wait before they can transmit.
- All 802.11ac frames are transmitted using the Aggregate MAC Protocol Data Unit (A-MPDU) frame format, even if only a single frame is being transmitted
- 802.11ac can use RTS/CTS to perform dynamic bandwidth operations
- Sends an RTS frame using a method known as a non-HT duplicate frame.
- If all requested channels are available, and if Station receives the RTS frames, it will transmit four CTS frames



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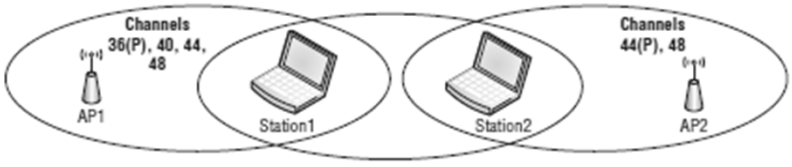
## The need for dynamic bandwidth Operation

Interfering laptops



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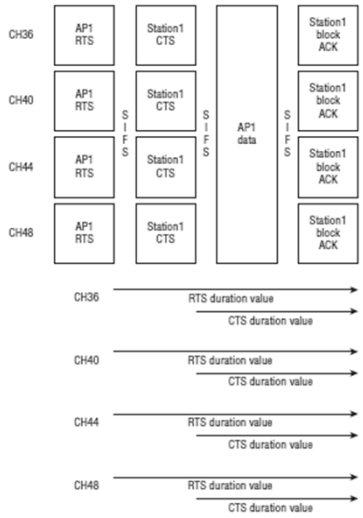
# Dynamic bandwidth operation

- Using RTS/CTS
- When AP1 receives all four CTS frames, it knows that all four channels are available



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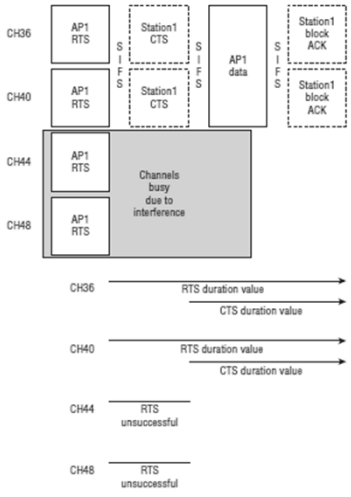
# What happens if all four channels are not available?

- When AP1 receives the CTS frames, it performs a 40 MHz data transmission on channels 36 and 40.
- Station1 then responds with two block ACK frames.



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## Beamforming

- Can occur from the AP to the client, or vice versa.
- Multiple radio chains in the AP transmit the same information through different antennas.
- APs time their transmissions so that the waves of all of the antennas arrive at the receiving radio at the same time and in phase with each other.
- Results in a signal increase of approximately 3 decibels
- Increase in signal strength can move the communications between the radios to a higher data rate



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## Explicit Beamforming

- 802.11ac only uses explicit beamforming
- Requires support by both the transmitter and receiver
- Uses an interactive calibration process to identify how to perform the transmission using the multiple radio chains
- Known as channel sounding.
- Beamformee processes each OFDM subcarrier and creates feedback information
- Uses the feedback matrix to calculate a steering matrix that is used to direct the data transmission to the beamformee

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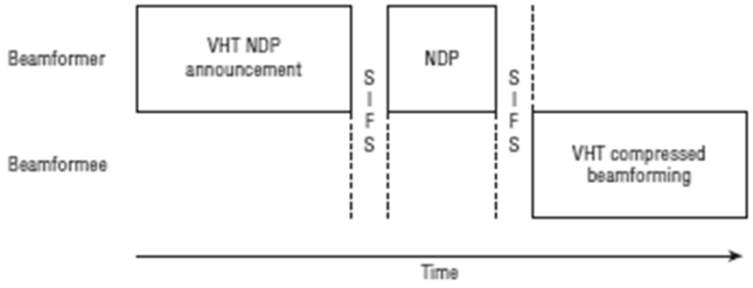
## Single-user beamform sounding process



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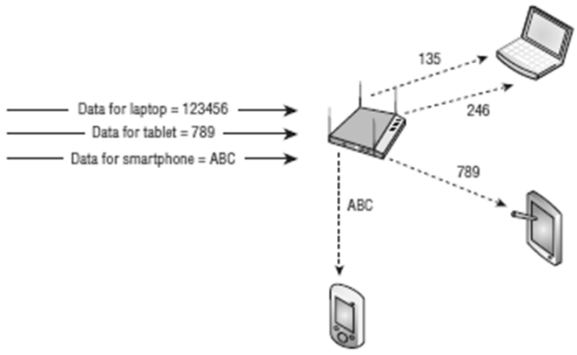
## Multiuser MIMO

Beamforming is a critical part of MU-MIMO



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## Multiuser Beamforming

- With single-user MIMO, beamforming is used to focus a signal to a client
- With MU-MIMO, the task of beamforming is not just performed for transmitting to a single client, it's performed for transmitting to up to four clients at a time.
- AP uses the feedback matrix from each of the beamformees to create a single steering matrix.



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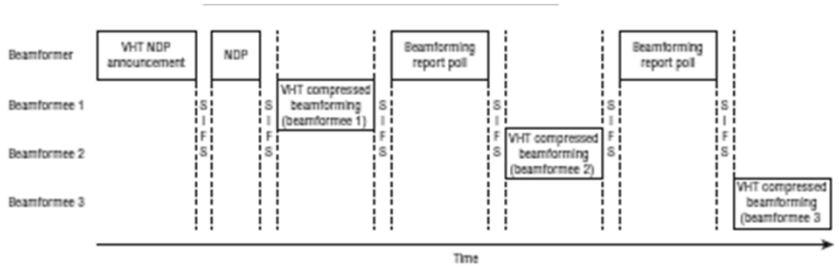
## Multiuser beamform sounding process



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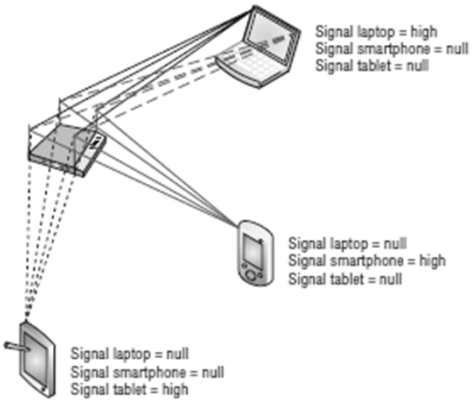
## Beamformed transmissions in a MU-MIMO environment



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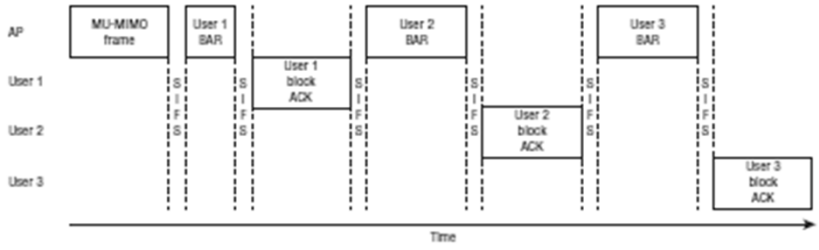
## MU-MIMO block acknowledgements

- AP sends a BAR frame to a user, waits for the block acknowledgment from that user, and then sequentially repeats the process with the other users.



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## Quality of Service

- Core concepts and procedures of quality of service (QoS) remain the same with 802.11ac.
- Queuing and transmission of QoS frames is handled differently than in single-user wireless environments
- During the construction of each multiuser frame, lower-priority frames can piggyback with the higher-priority frame, providing they do not increase the time needed to transmit the primary data and providing the stations they are being sent to are spatially distinct.



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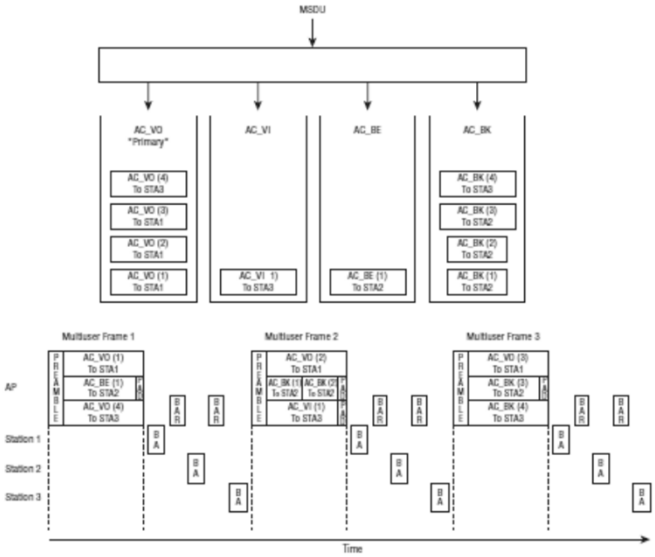
## MU-MIMO and QoS



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## Infrastructure Requirements

- Ethernet
  - Second phase of 802.11ac may require faster uplink technology than Gigabit Ethernet
- Power
  - Transitioning to PoE+ will be inevitable
  - Upgrading the network to provide 802.3at (PoE+) power of 30 watts is highly recommended and most likely will become a necessity



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## 802.11ac in a SOHO or Home

- Device Radios
  - To upgrade, you will need to purchase a dual-radio AP to continue to provide support for older 2.4 GHz devices.
- Data Flow/Usage
  - It is not likely that your Internet connection is fast enough to support the throughput that an 802.11ac AP can provide

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## 802.11ac in a SOHO or Home

- Spatial Streams
  - Operating 802.11ac multiple-spatial-stream devices along with single-spatial-stream devices, the single-stream devices will decrease the performance
- Wider 802.11ac Channels
  - Takes more power to process the data that is transmitted across wider channels
- MU-MIMO
  - Can only occur if the devices are spatially separated, since beamforming will not work properly if two devices are near each other.



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## Wi-Fi Alliance Certification

- Wi-Fi CERTIFIED ac products are tested for both the mandatory and optional baseline capabilities
- Wi-Fi CERTIFIED ac devices only operate in the 5 GHz frequency band.
- Wi-Fi CERTIFIED ac devices support both Wi-Fi Multimedia (WMM) quality-of-service mechanisms and WPA2/WPA2 security mechanisms

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## Wi-Fi CERTIFIED ac baseline requirements (phase 1)

| Feature | Mandatory | Optional |
|---|---|---|
| Channel width | 20, 40, 80 MHz | 80_80, 160 MHz |
| Modulation and coding | MCS 0–7 | MCS 8,9 |
| Spatial streams | One for clients, two for APs | Two to eight |
| Guard Interval | Long (800 nanoseconds) | Short (400 nanoseconds) |
| Beamforming feedback | | Respond to beamforming sounding |
| Space-time block coding (STBC) | | Transmit and receive STBC |
| Low-density parity check (LDPC) | | Transmit and receive LDPC |
| Multiuser MIMO | | UP to four spatial streams per client, using the same MCS |



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## Chapter 19 Summary

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