Speech Task Overview 2

Болотов Дмитрий

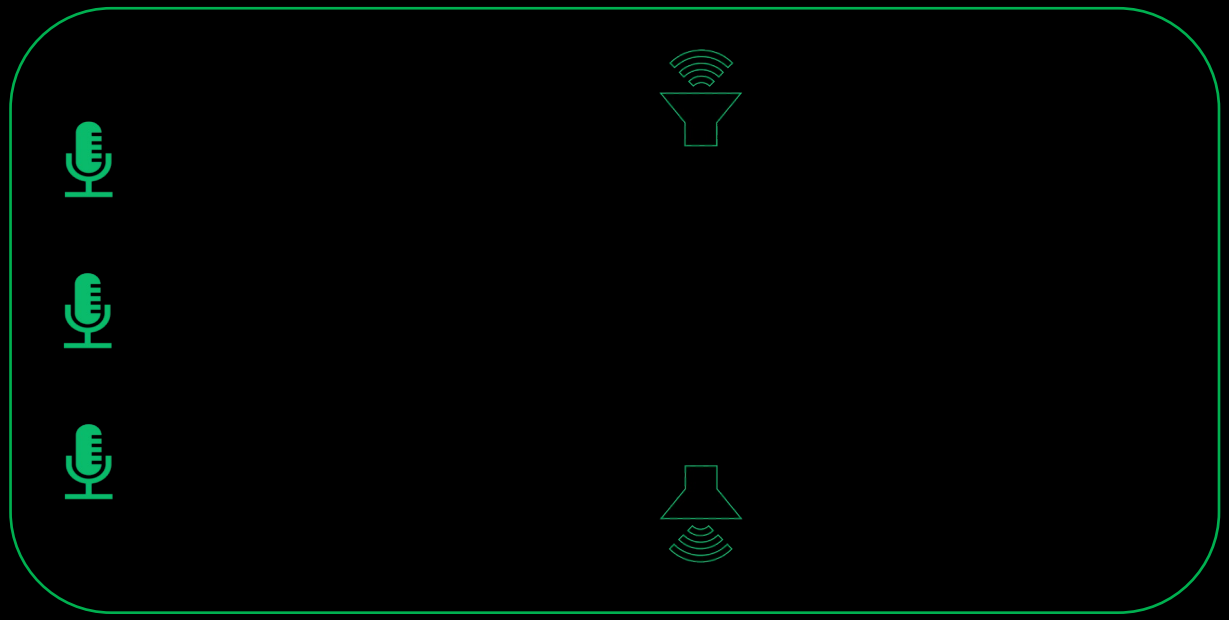
План:

- Voice assistant pipeline
- User perceived latency
  - Keyword detection
  - Endpoint detection


Sber 75″
miniLED
Салют ТВ


18:41

Voice assistant pipeline



Voice assistant pipeline

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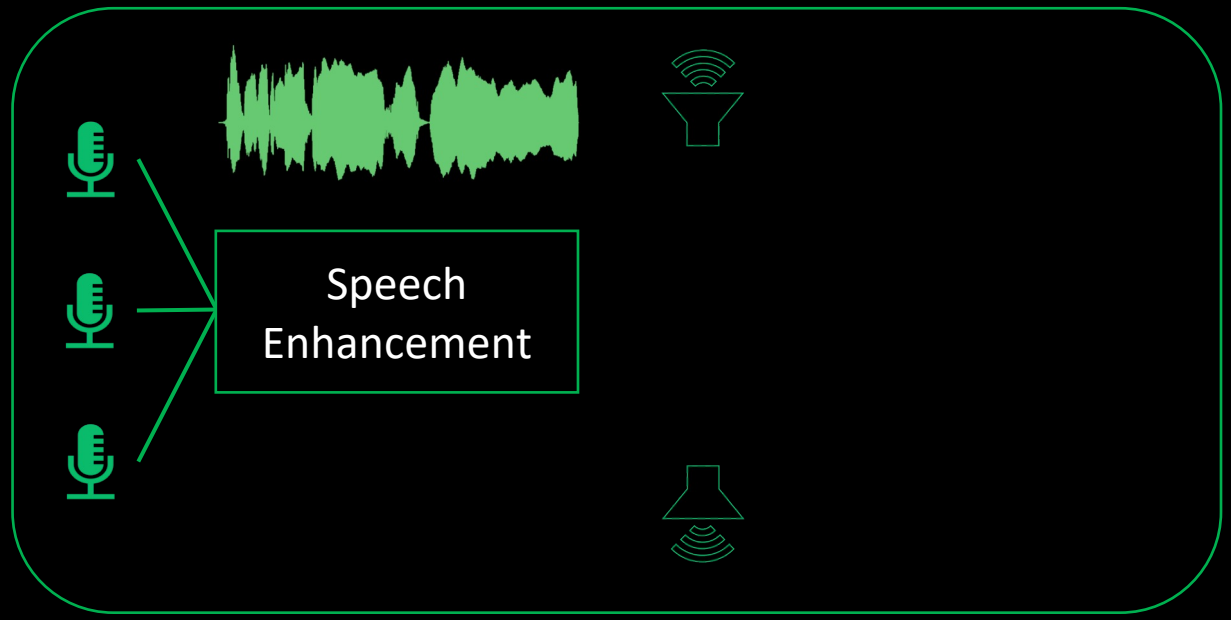

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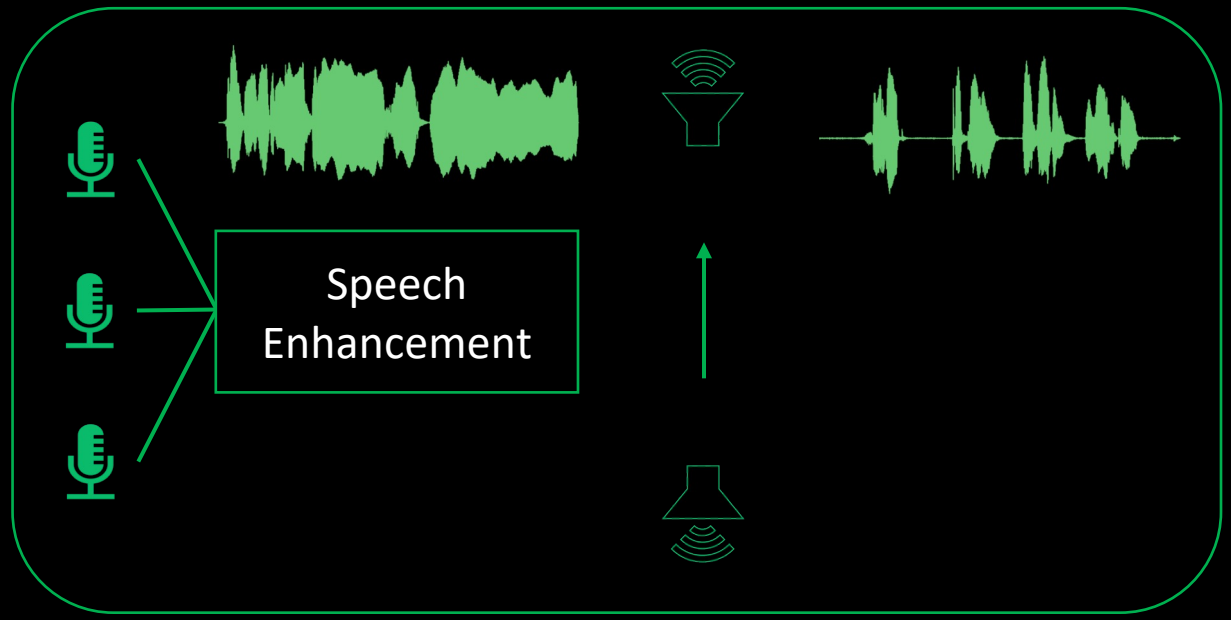

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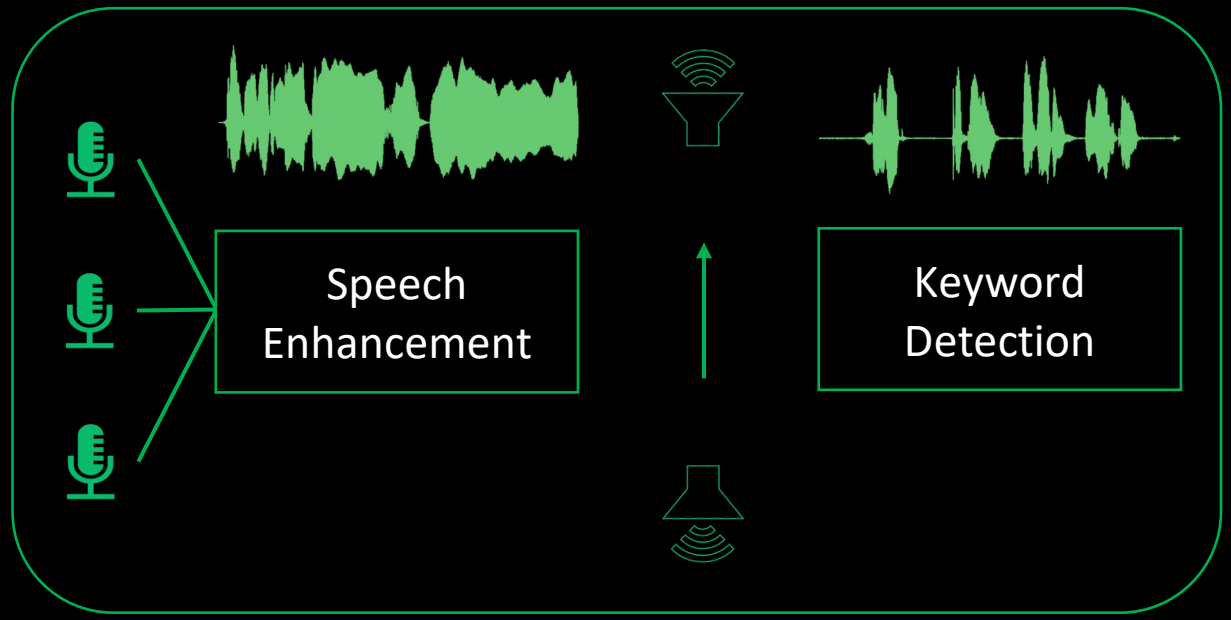

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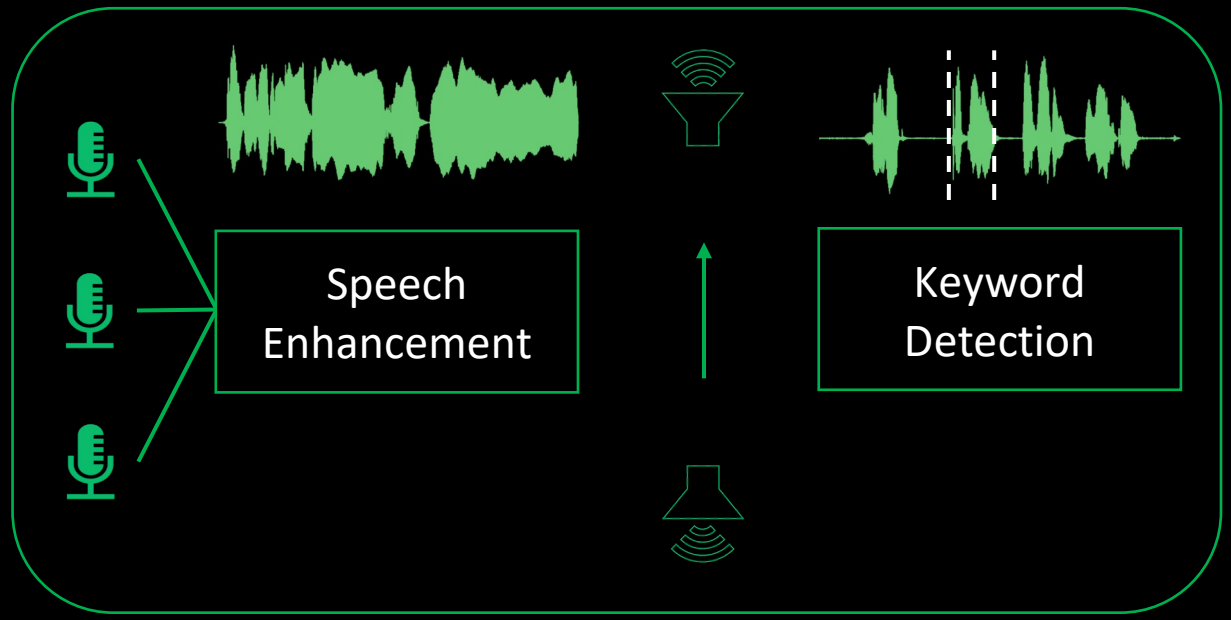

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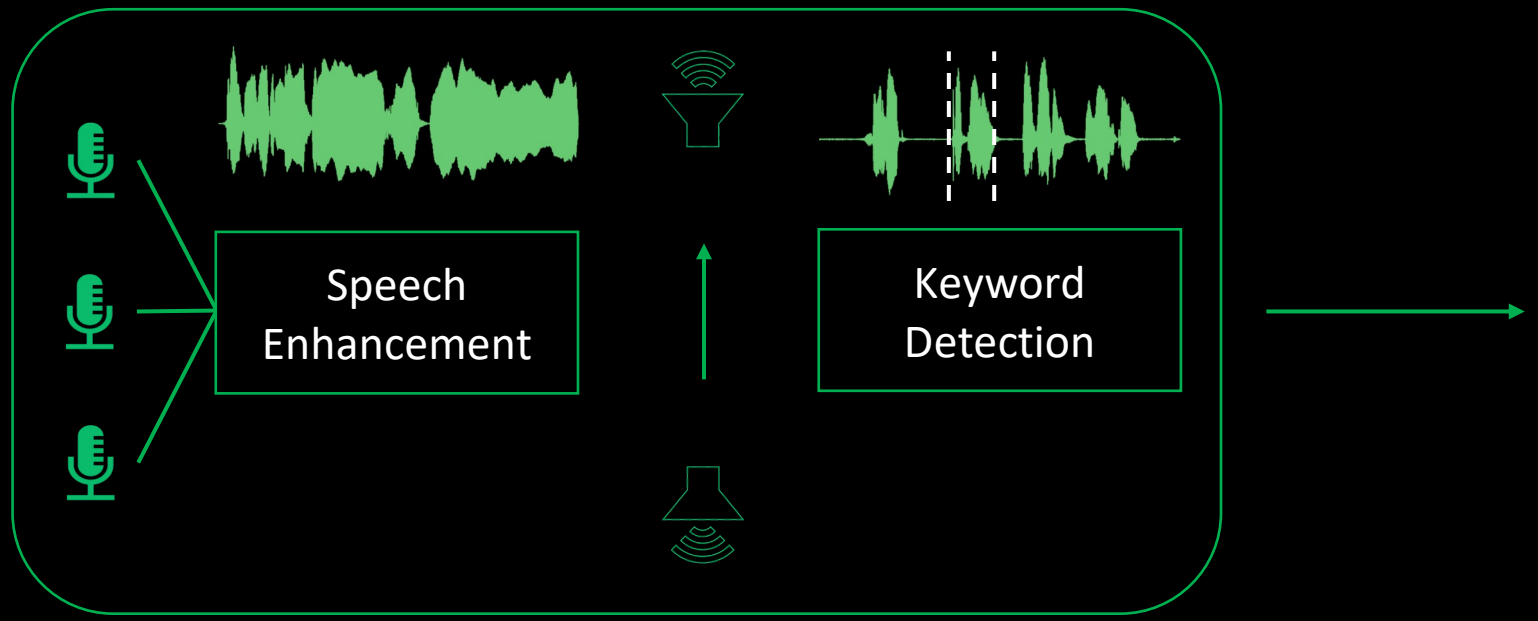

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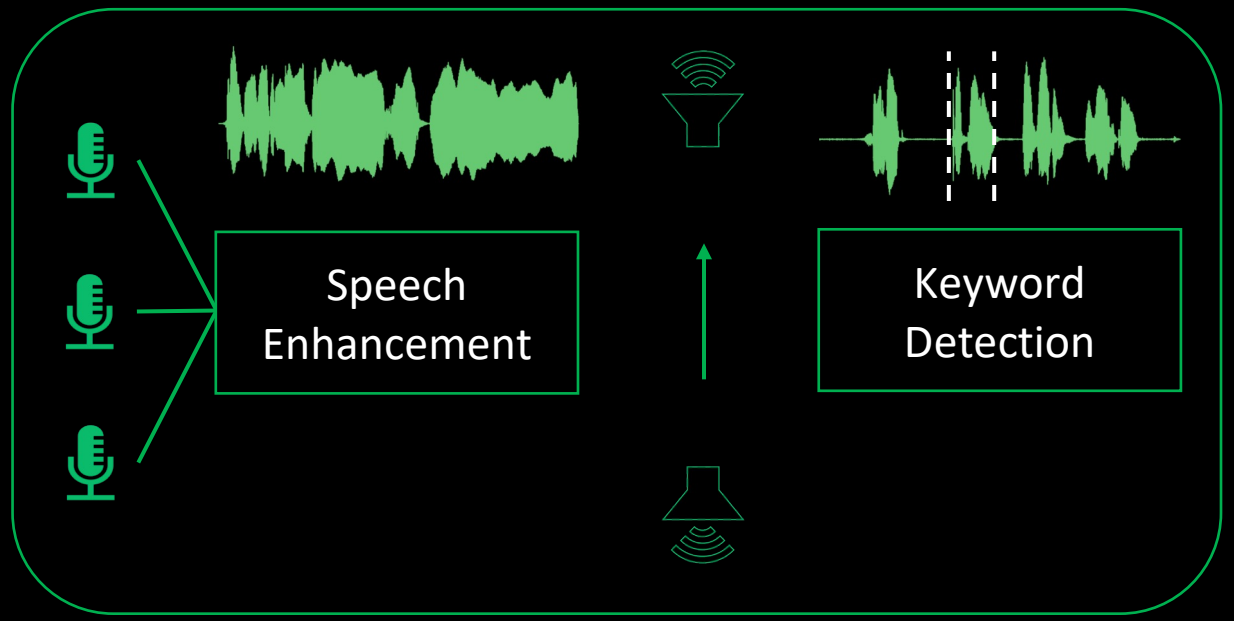
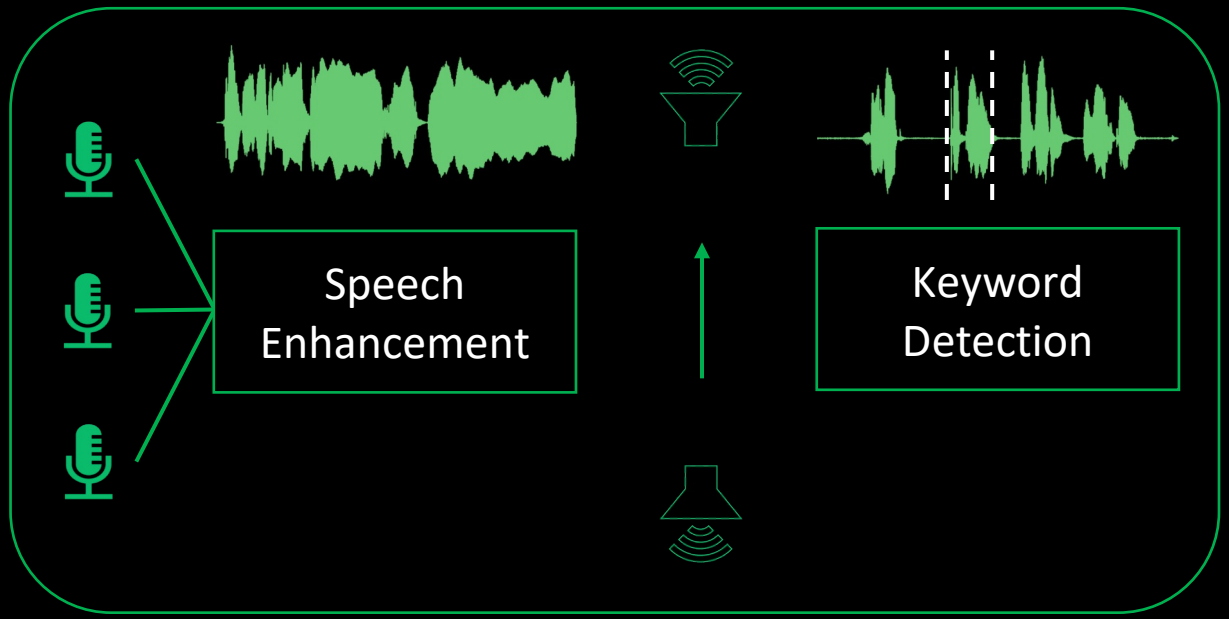


Keyword
Validation

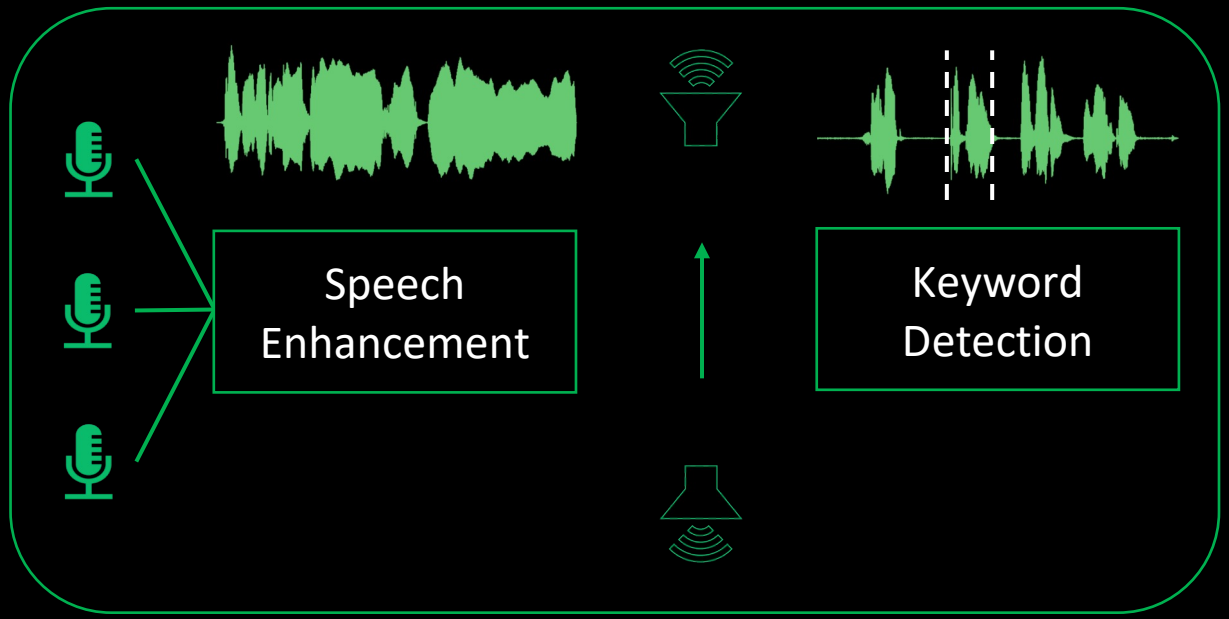
Voice assistant pipeline



Keyword Validation

Intended Query Detection

Voice assistant pipeline



Keyword Validation

Intended Query Detection

Speech Recognition

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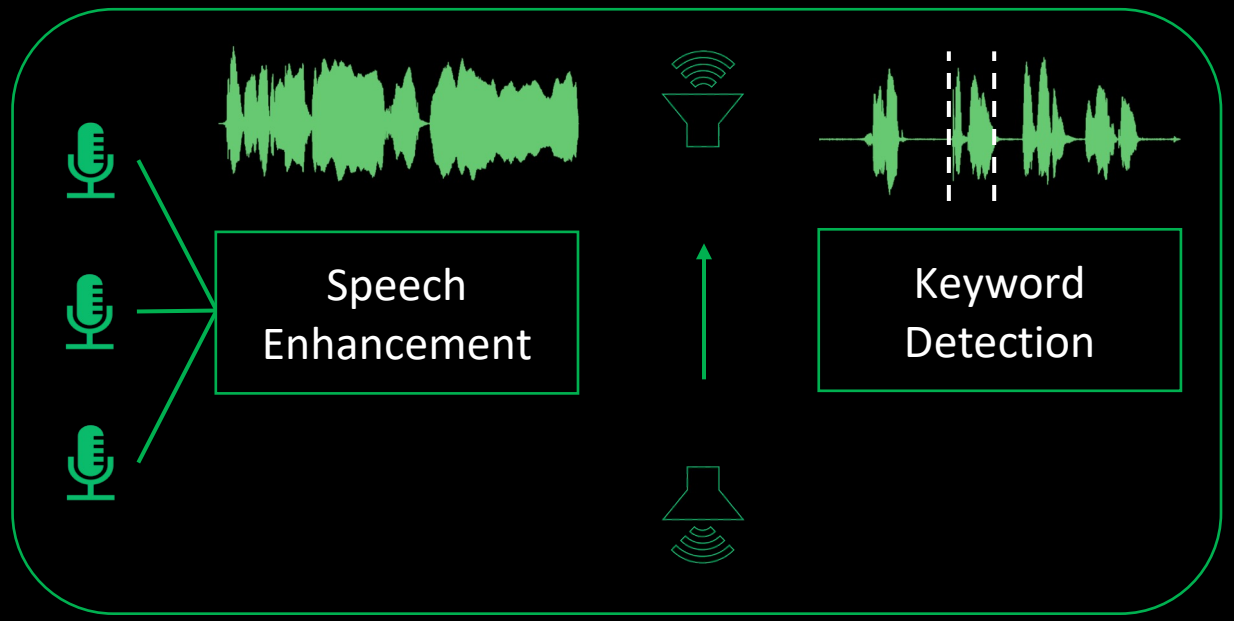


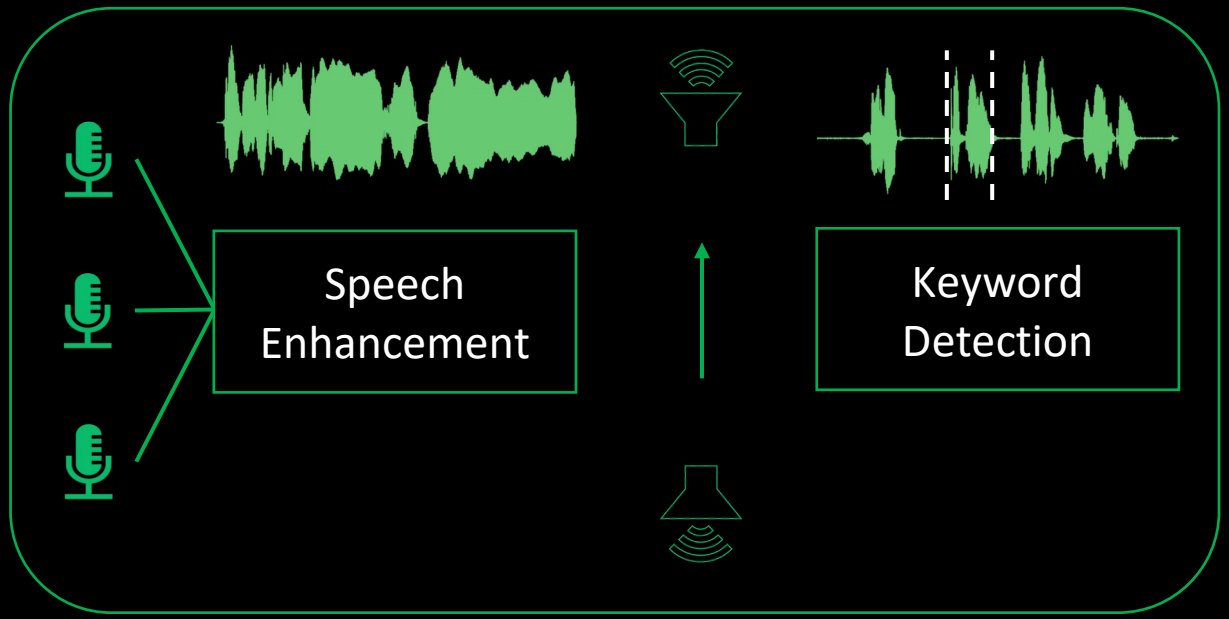
Keyword Validation

Intended Query Detection

Speech Recognition

Endpoint Detection

Voice assistant pipeline



Keyword Validation

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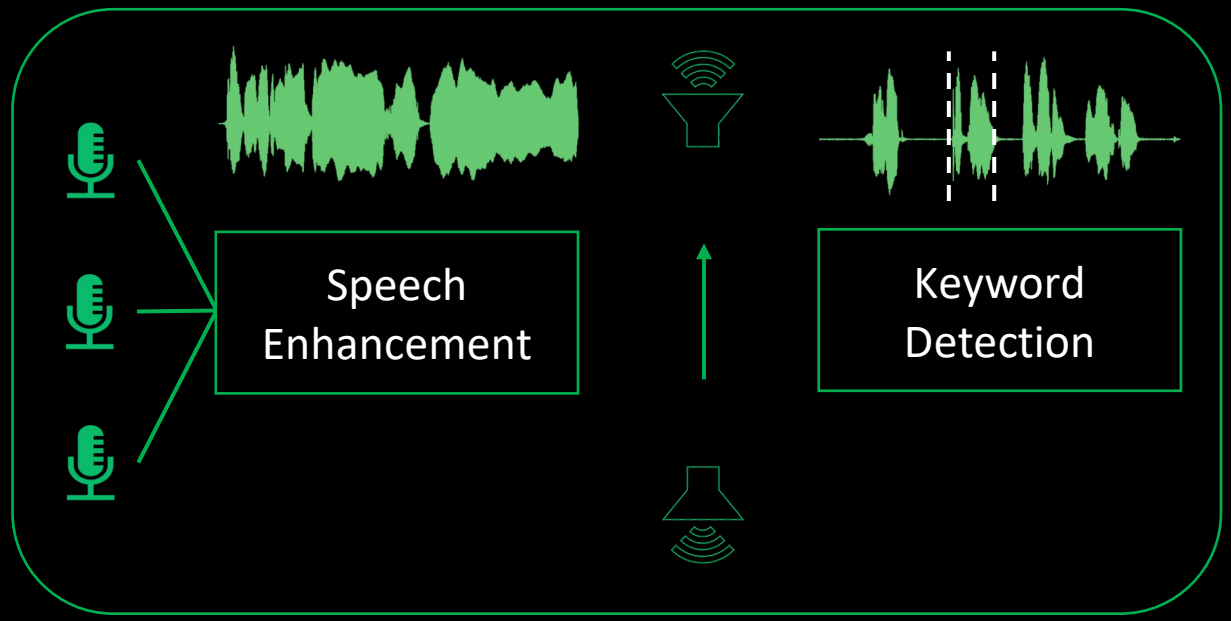
Whisper Detection

Voice assistant pipeline



Keyword Validation

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Emotion Detection

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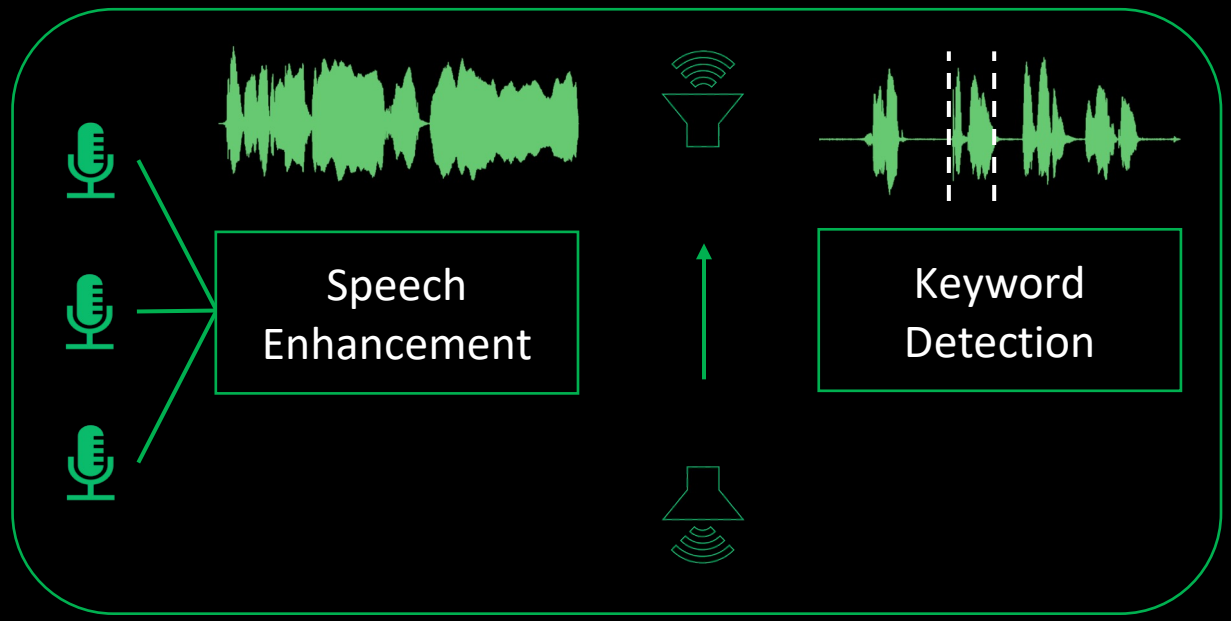

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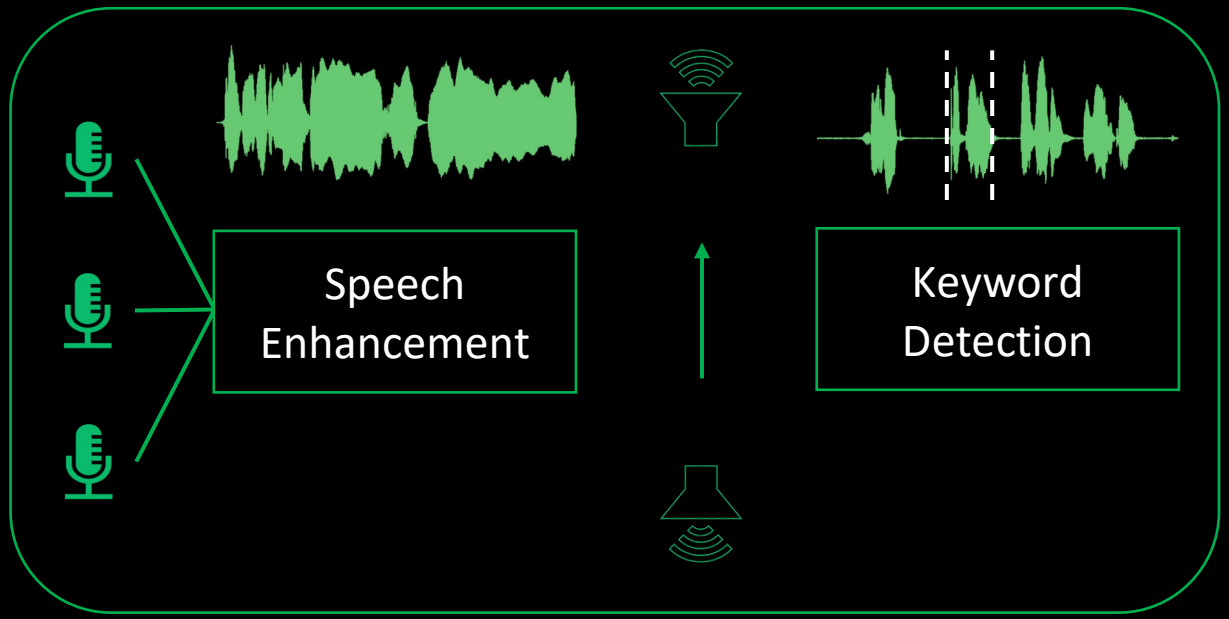
- Emotion Detection
- Speaker Identification

Voice assistant pipeline



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- Speech Separation

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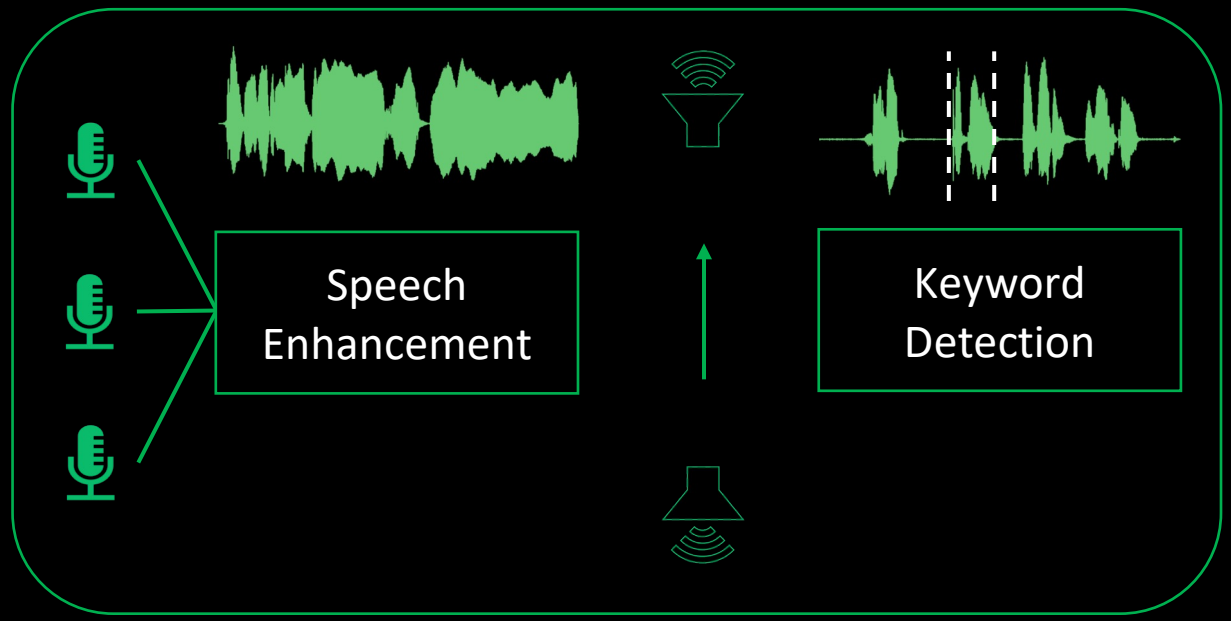

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салют какая погода в москве

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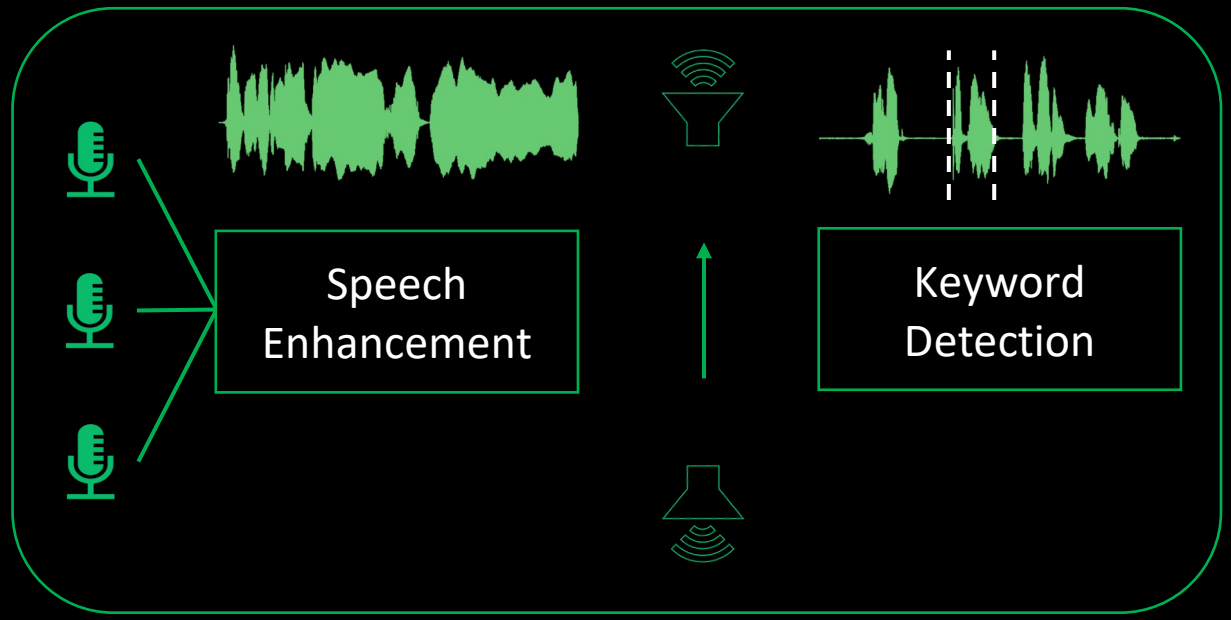

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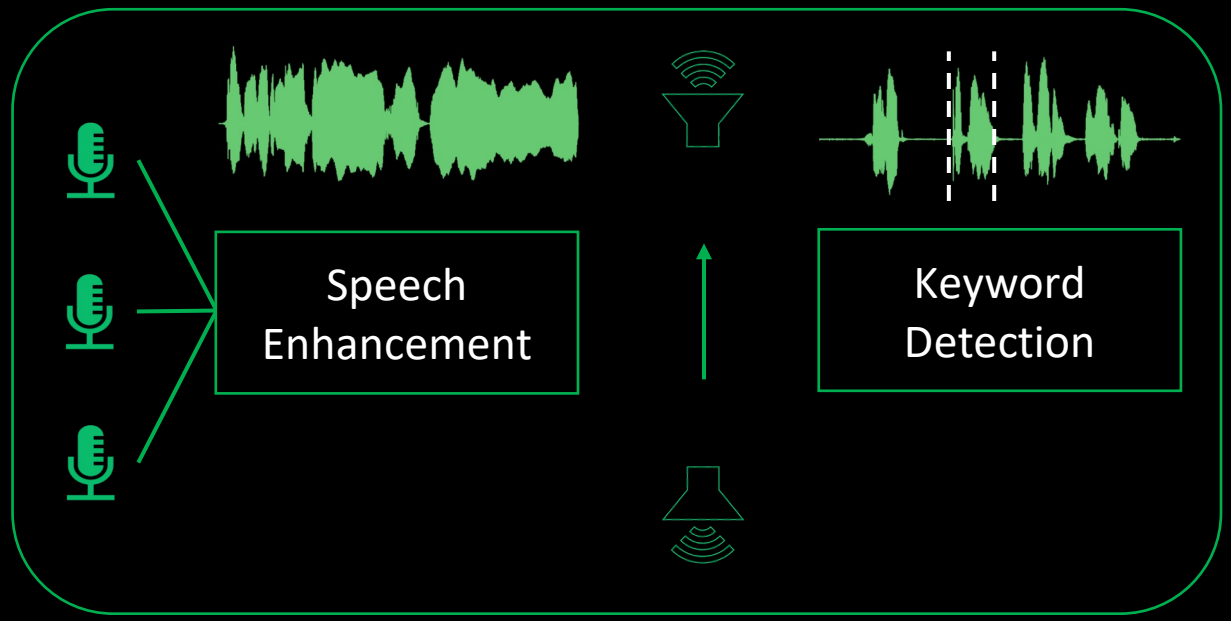

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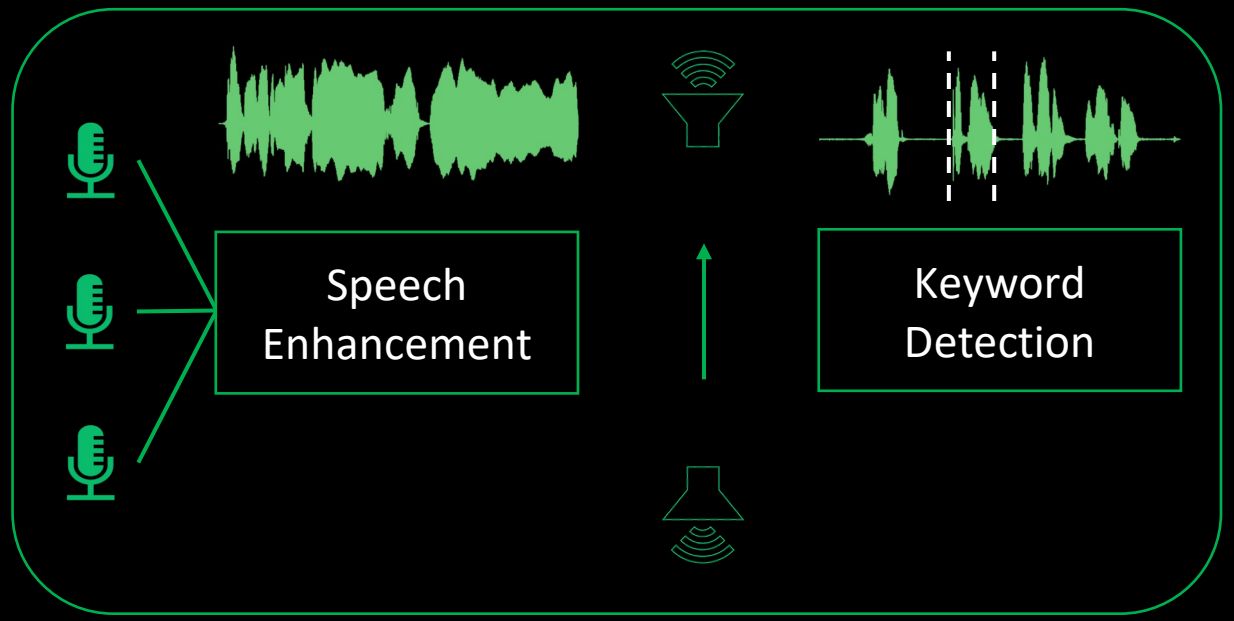

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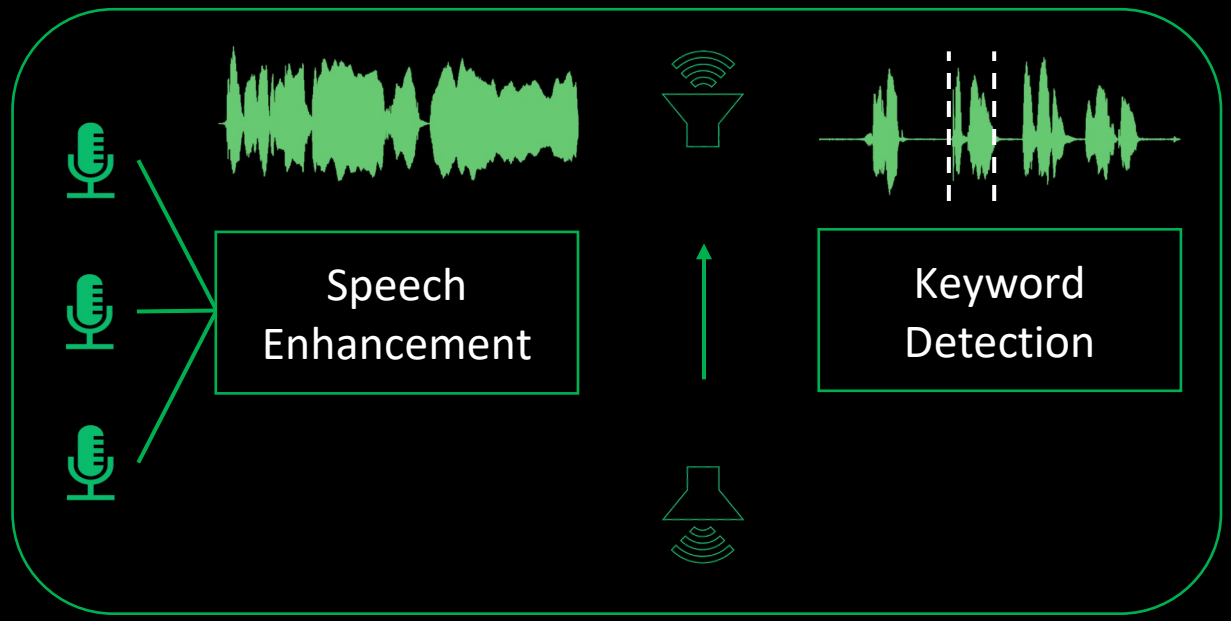

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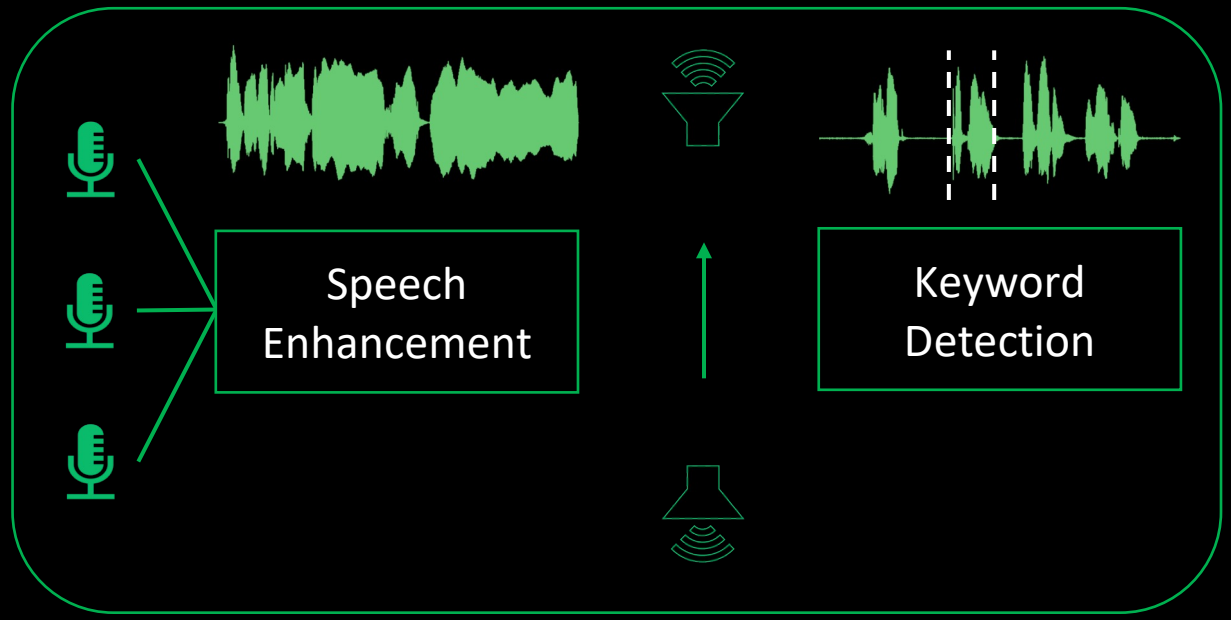

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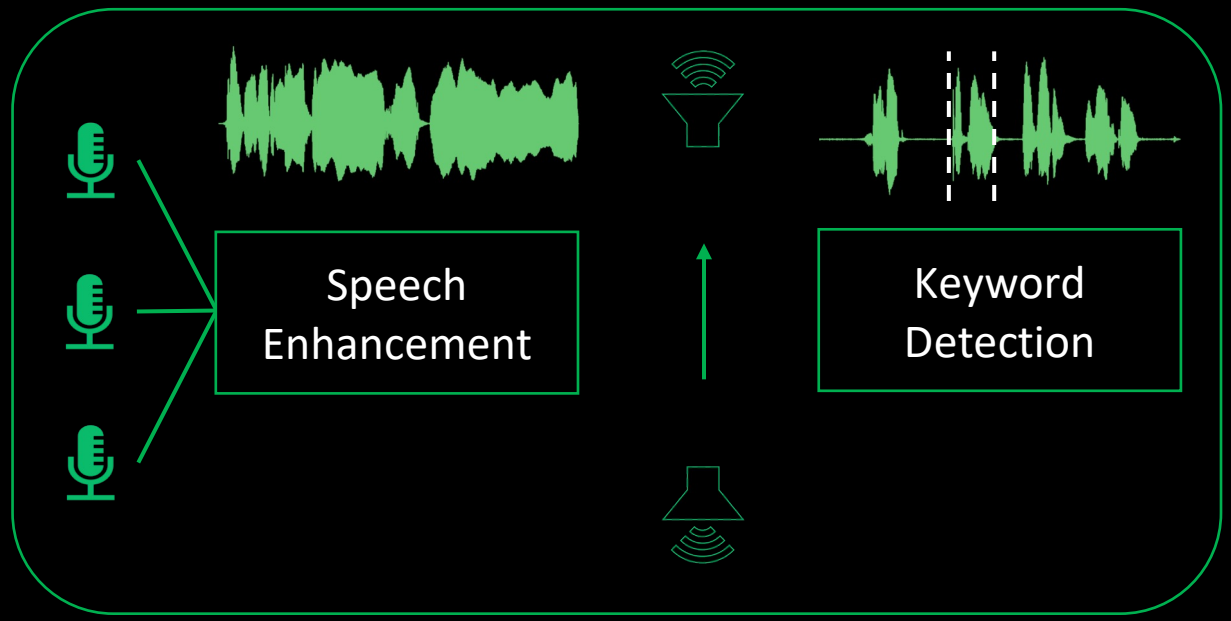
Салют, какая погода в Москве?

Assistant platform:
Intent recognition, Search,
Dialog Management, Skills

Voice assistant pipeline



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Салют, какая погода в Москве?

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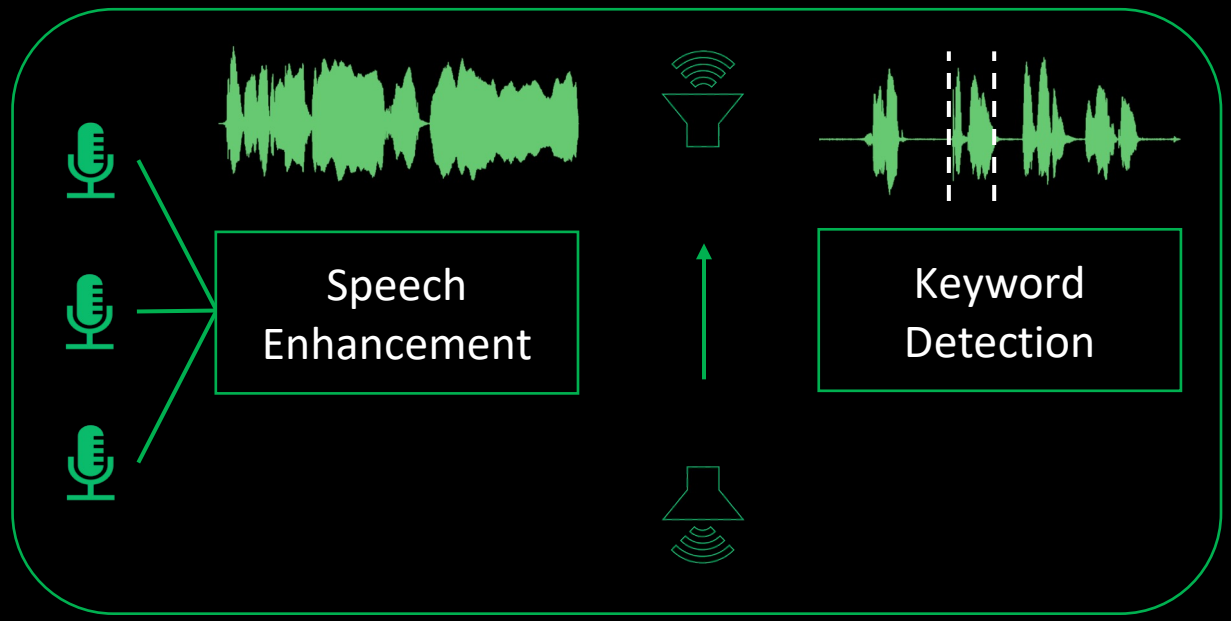

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Салют, какая погода в Москве?

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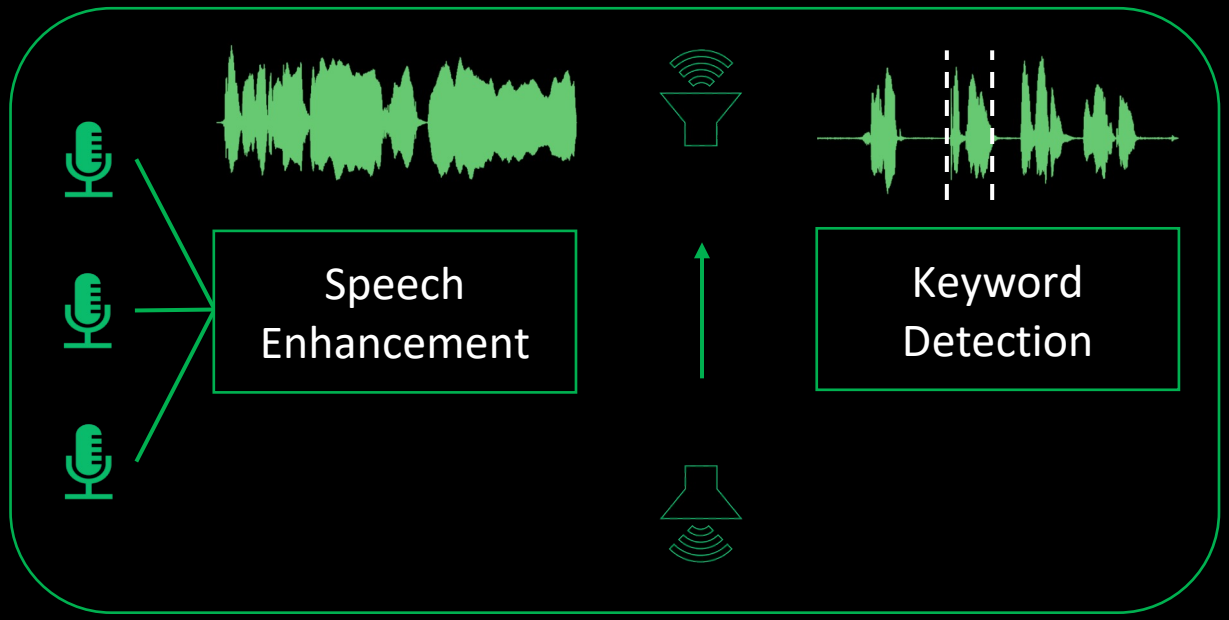
Сейчас в Москве +15 °C

Voice assistant pipeline



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Салют, какая погода в Москве?

Assistant platform:
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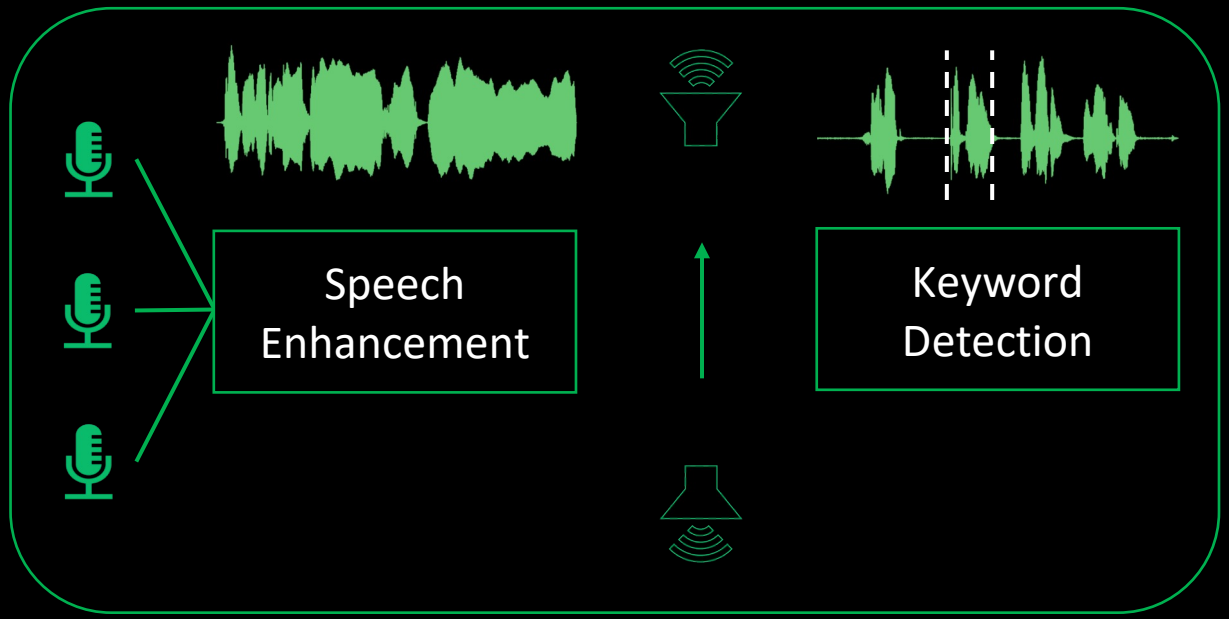
Сейчас в Москве +15 ºC

Text Normalization

Speech Synthesis

Voice assistant pipeline



Keyword Validation

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Салют, какая погода в Москве?

Assistant platform:
Intent recognition, Search,
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Сейчас в Москве +15 ºC

Text Normalization

Speech Synthesis

Voice assistant pipeline

Какие основные требования у пользователей?
- Простота настройки и интеграции с другими системами
- Приватность и безопасность
- Качество звука и синтеза речи
- Поддержка широкого спектра возможностей
- Скорость отклика

User perceived latency

Скорость отклика
- Быстрое выполнение команд, без задержек и пауз

User perceived latency – метрика, отражающая воспринимаемое пользователем время задержки между действием и реакцией системы.

В нашем случае можем выделить два примера:
- Произношение активационной фразы <-> активация колонки
- Произношение голосового запроса <-> получение ответа

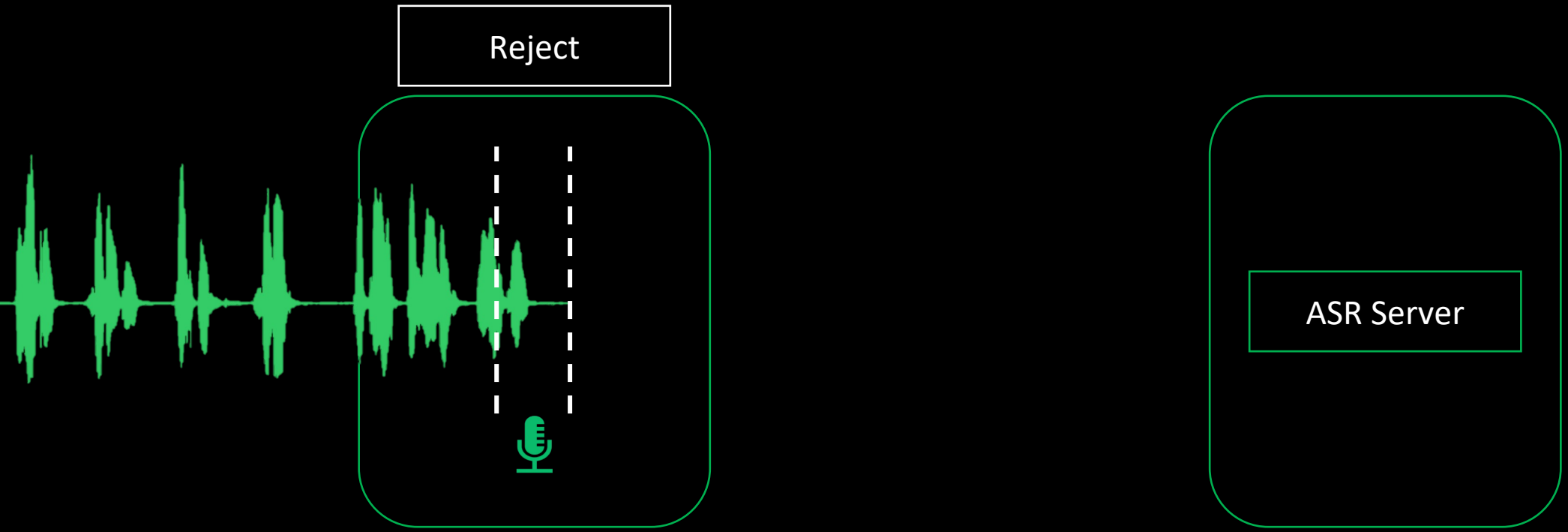
Keyword detection

Основная задача в рамках Voice Assistant Pipeline
- Детектирование ключевых фраз в аудиопотоке для активации устройства

- Салют
- Сбер
- Афина
- Джой

Keyword detection: on-device

Keyword detection: on-device



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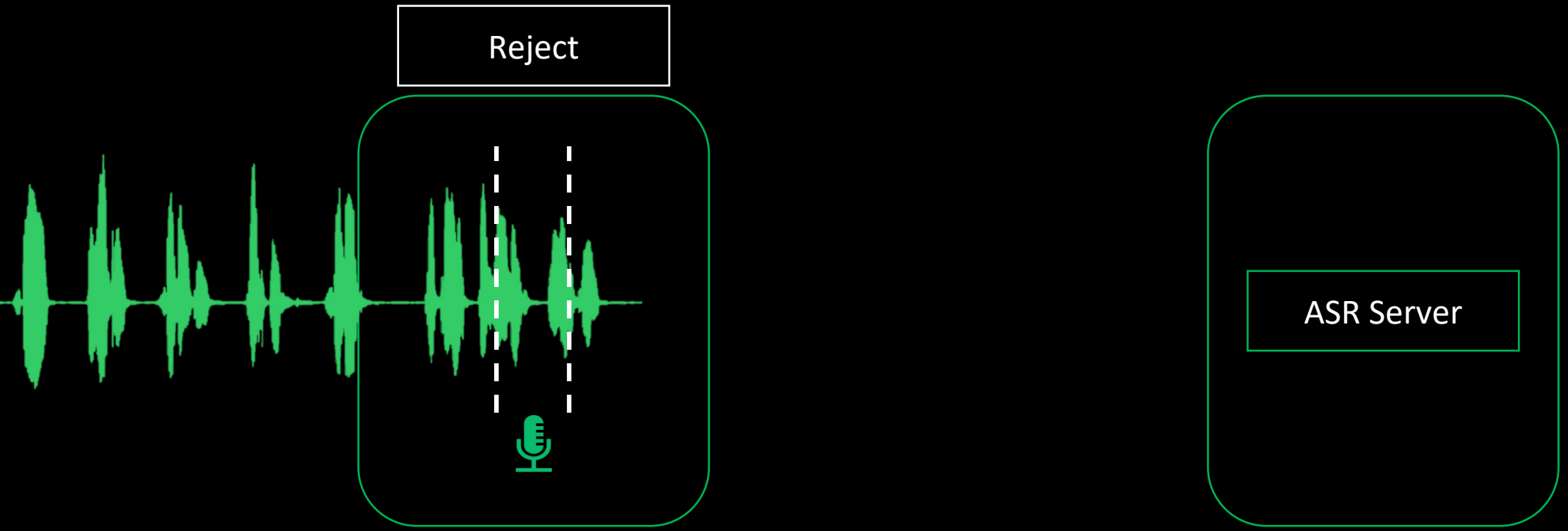

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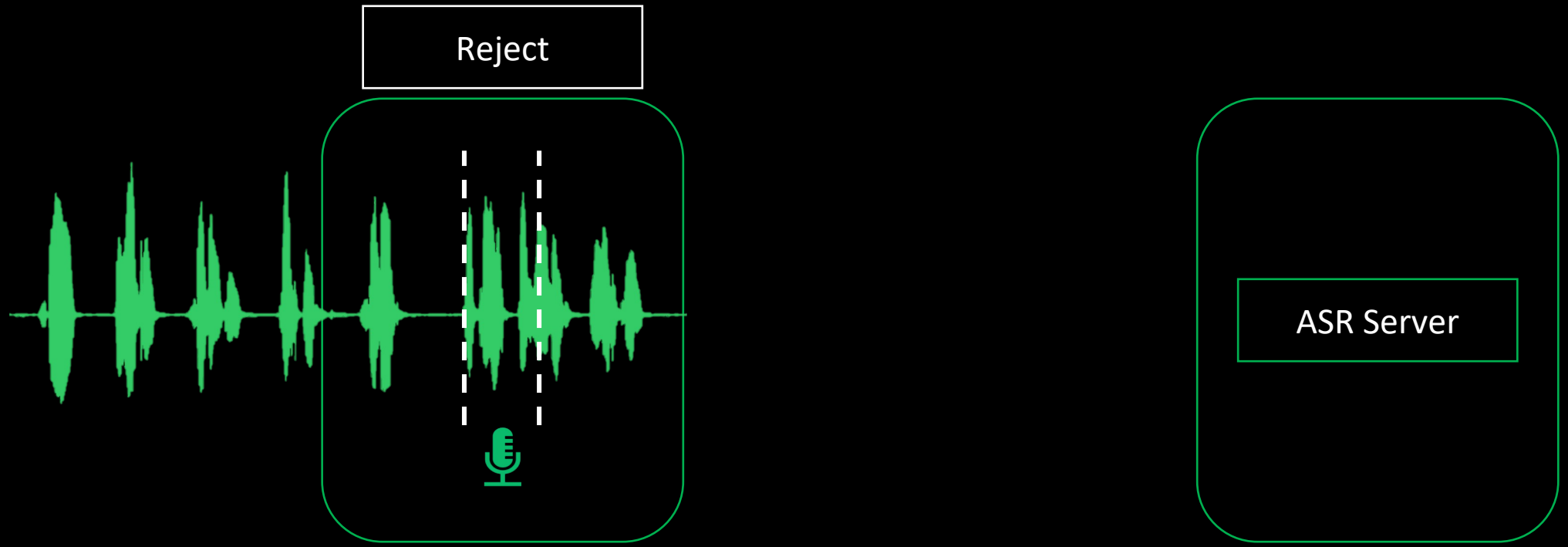

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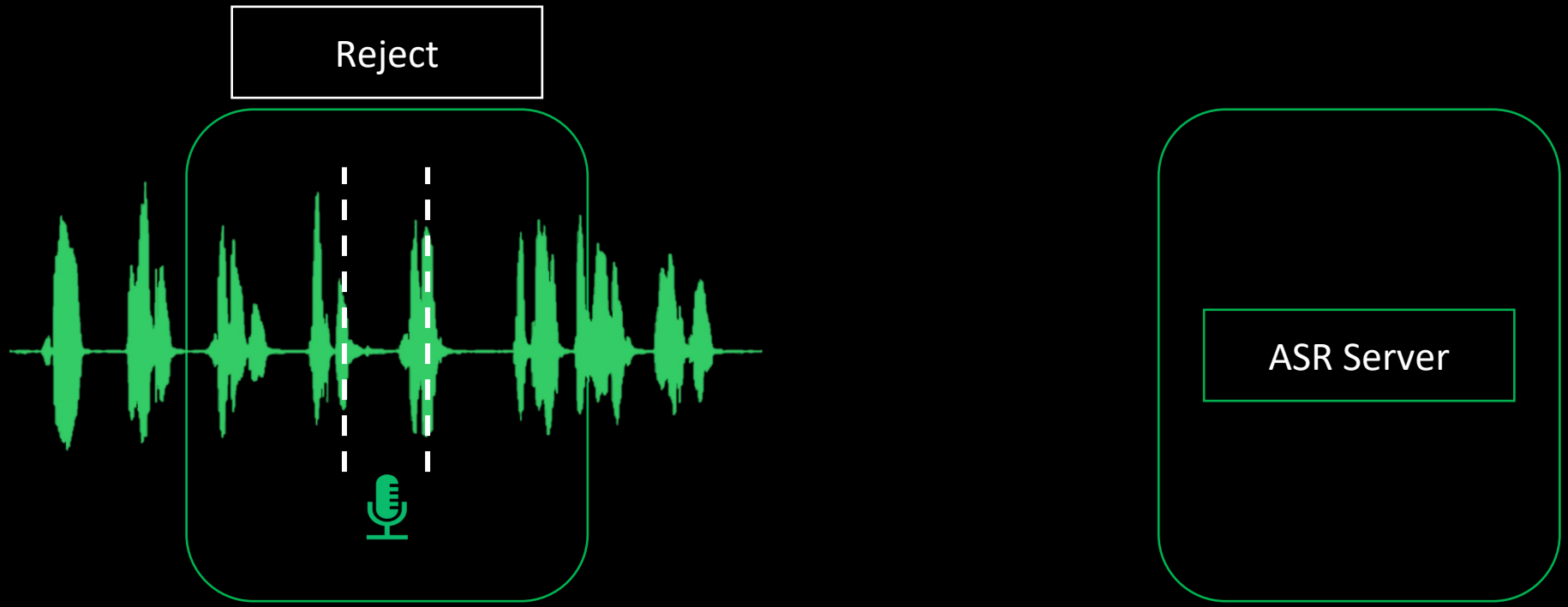

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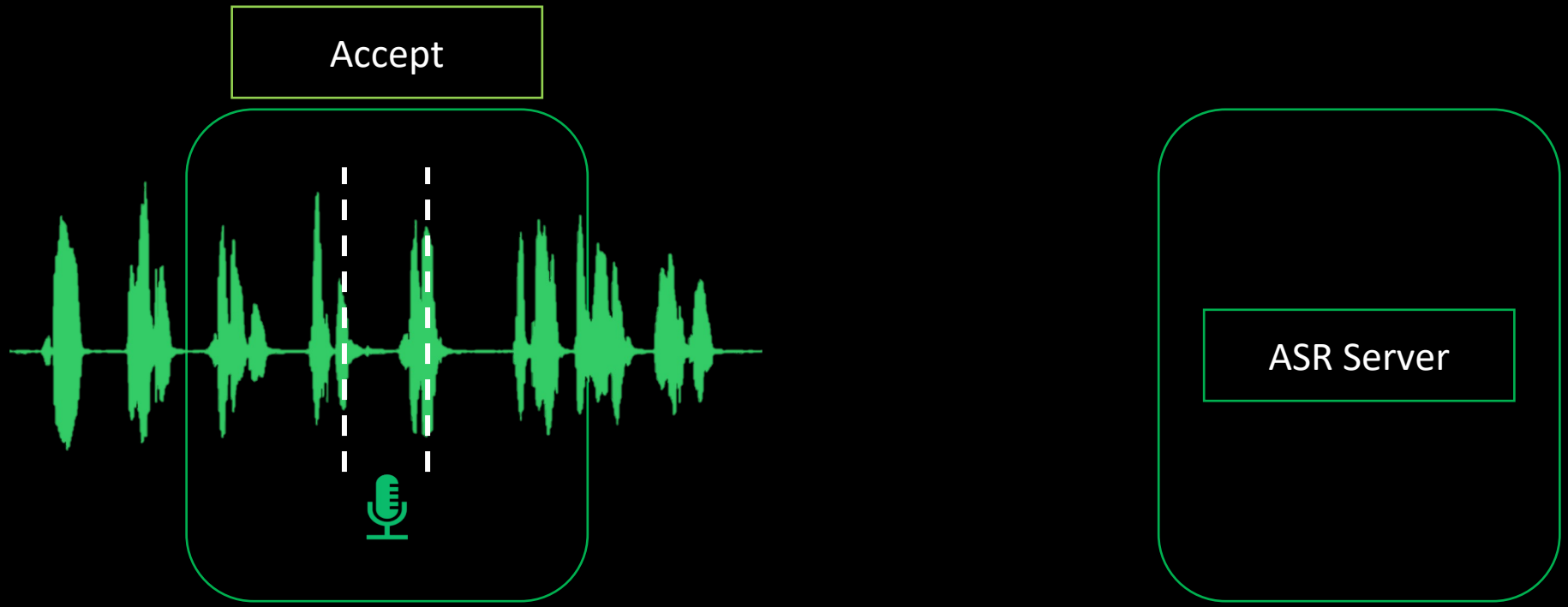

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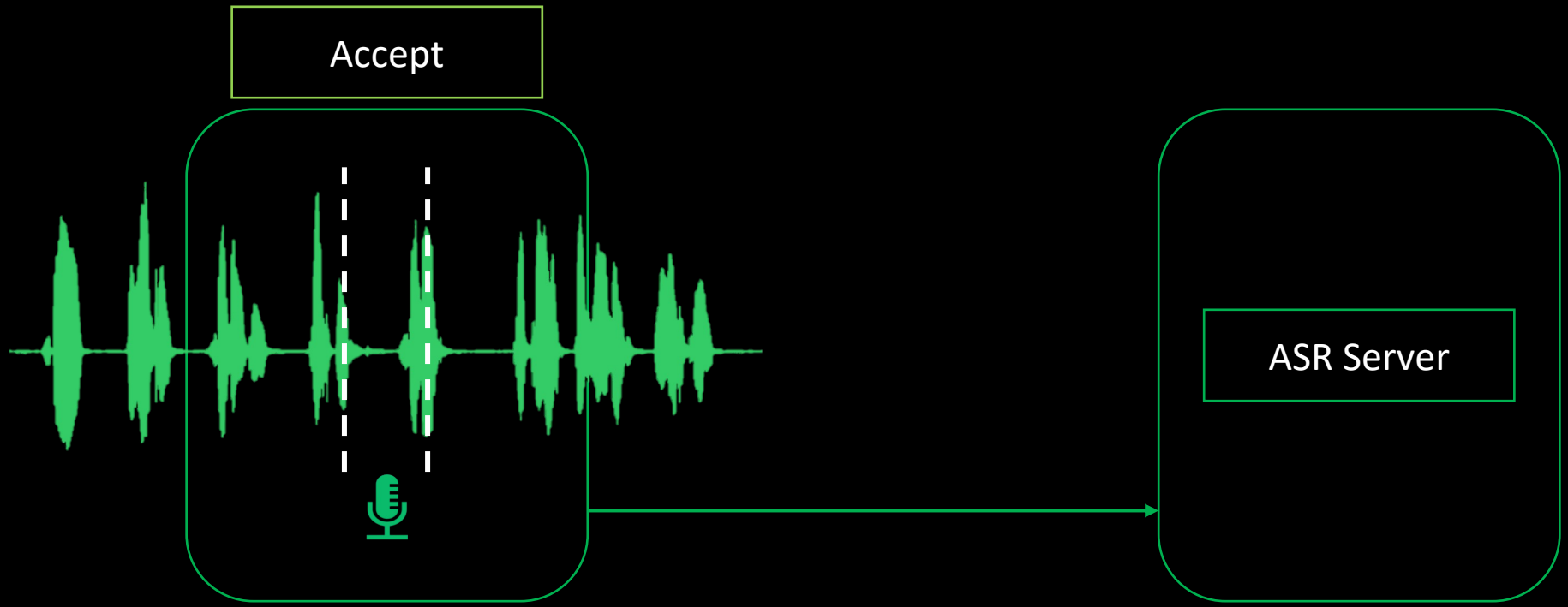

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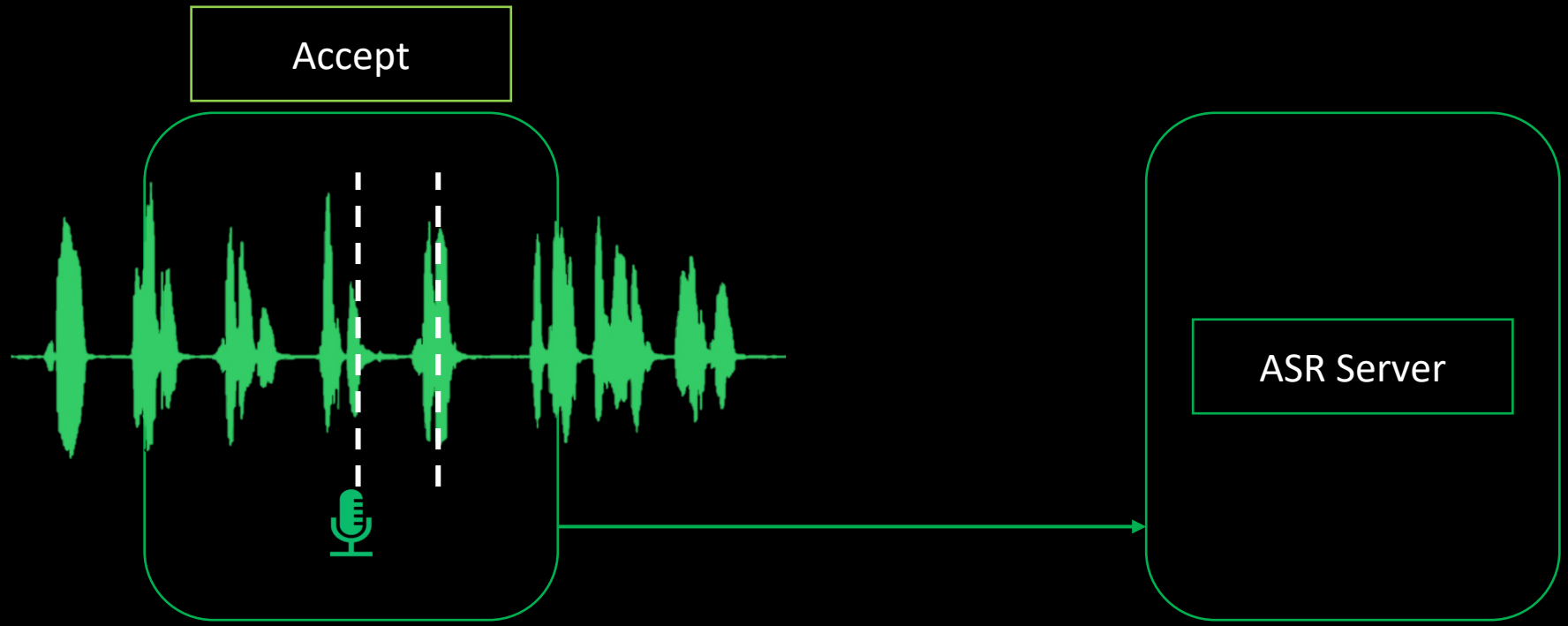

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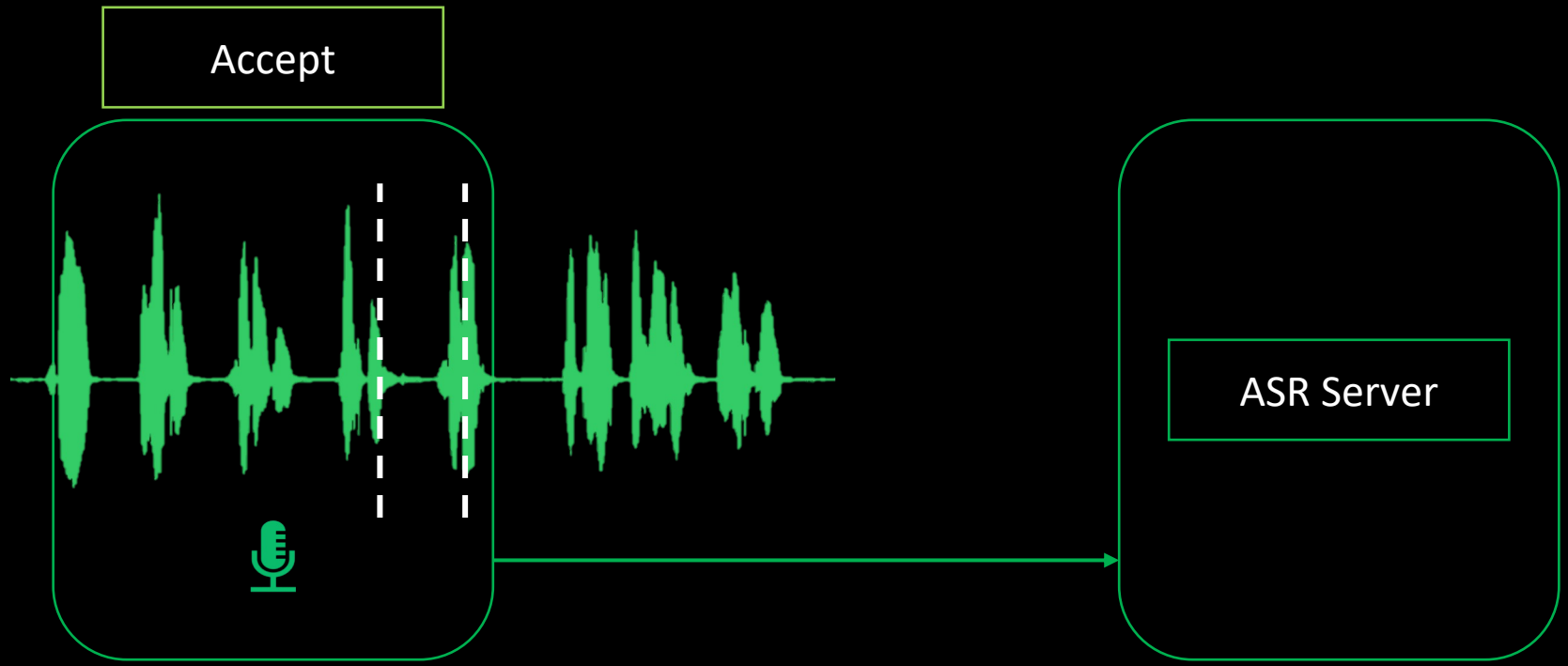

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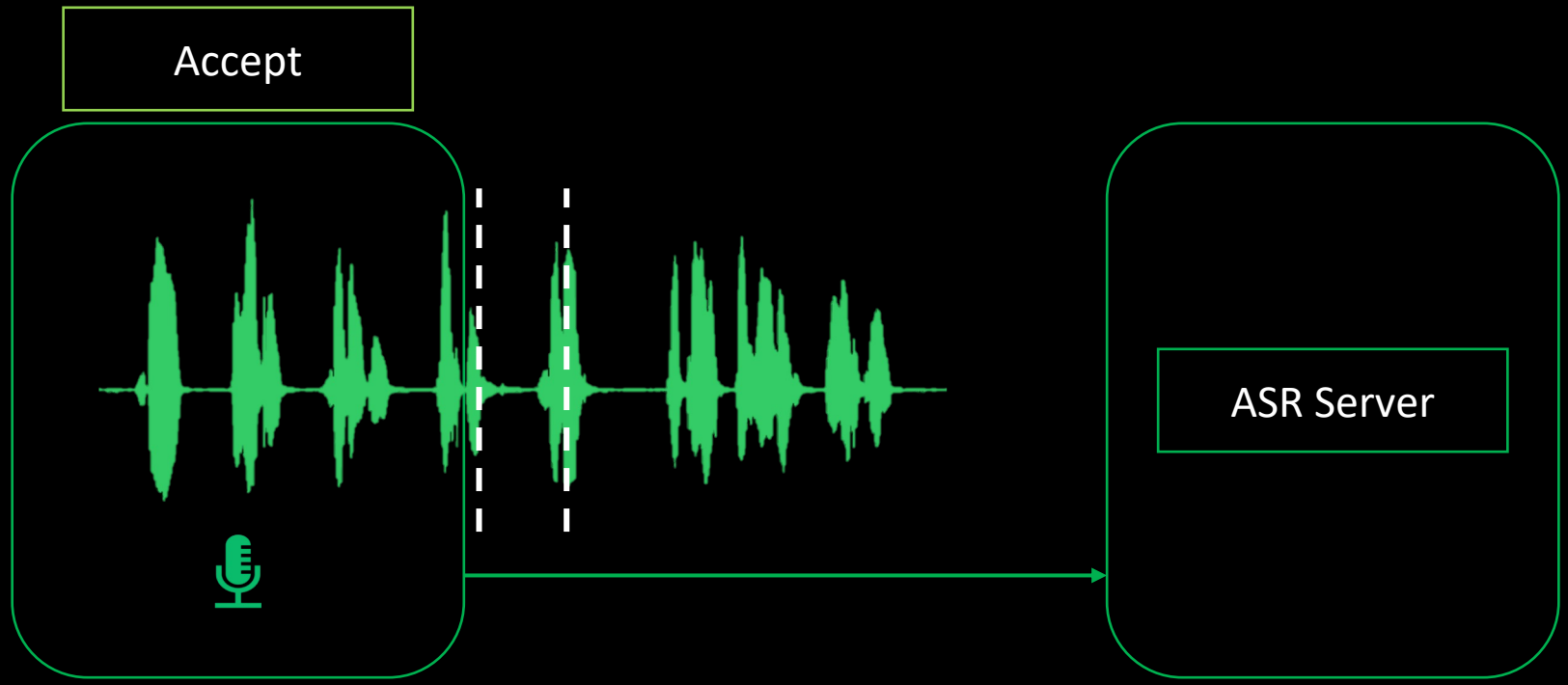

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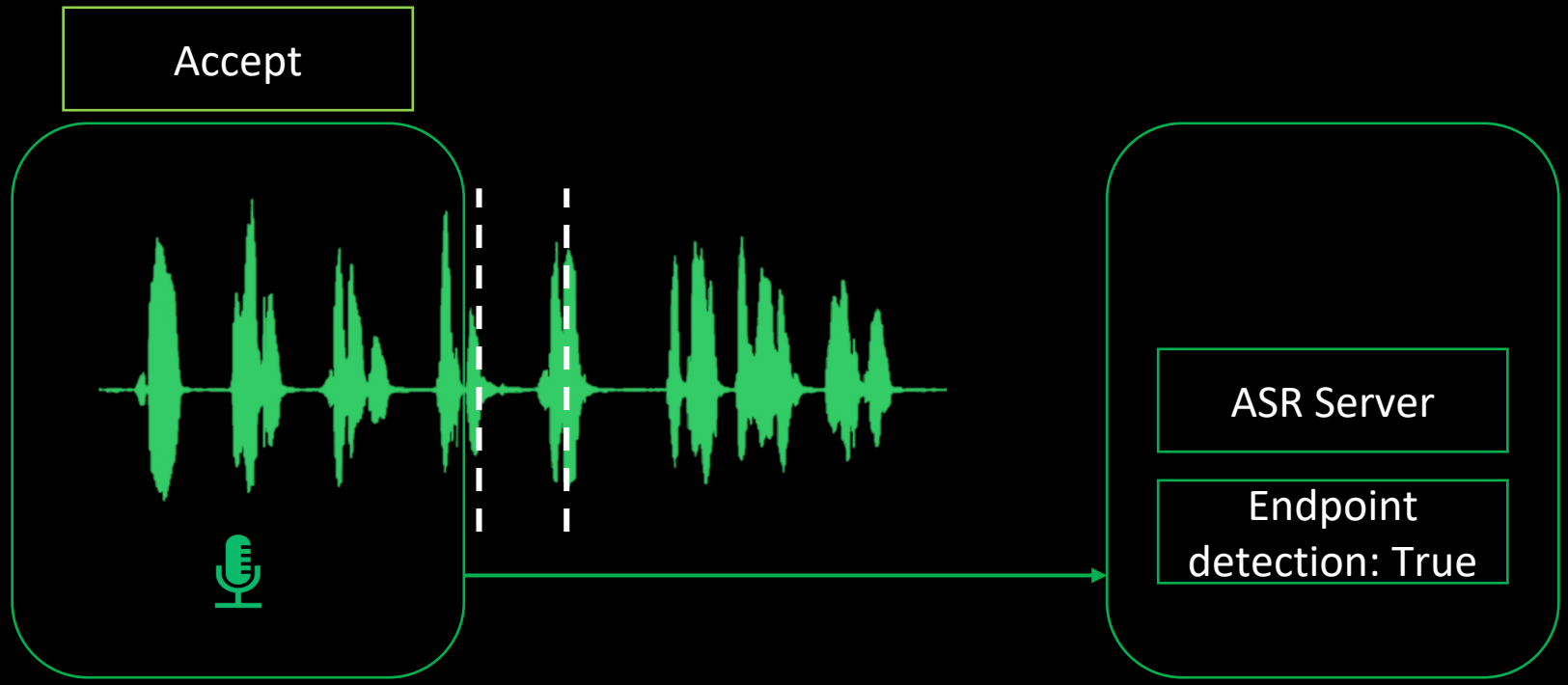

Keyword detection: on-device

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ASR Server

Endpoint detection: True

Assistant platform:
Intent recognition, Search,
Dialog Management, Skills

Keyword detection: on-device

Преимущества:

- Простота реализации системы
- Скорость инференса

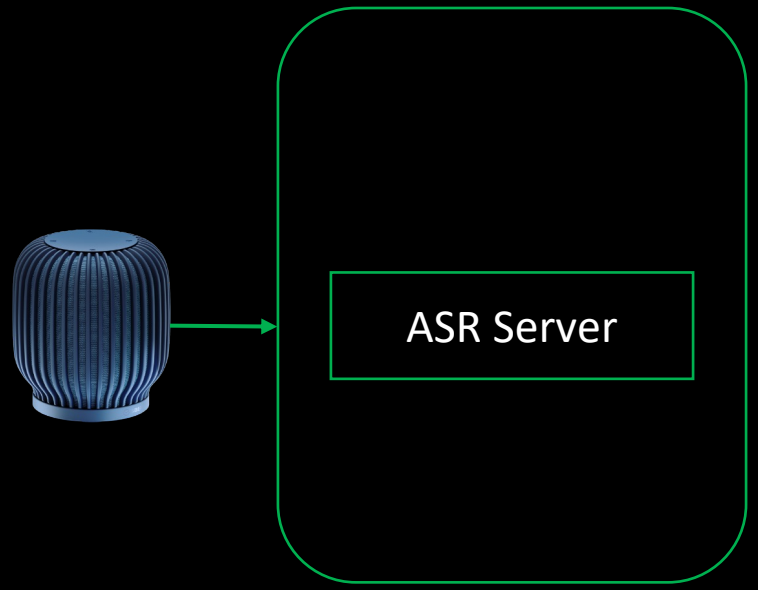
Недостатки:
- Компромисс между точностью, ресурсоемкостью и скоростью

Keyword detection: on-device

Почему on-device?

Keyword detection: on-device

Почему on-device?
- Конфиденциальность



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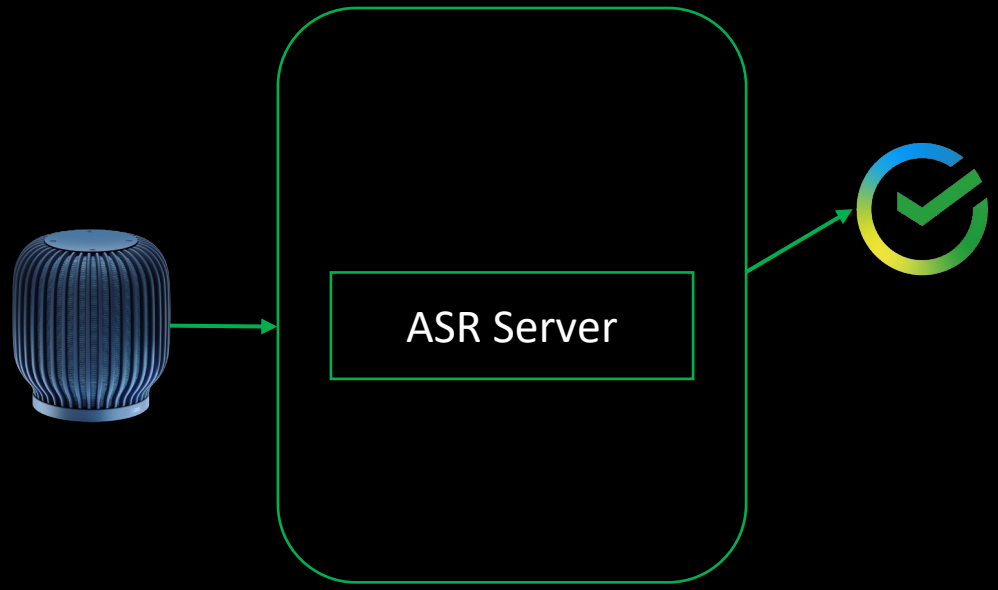

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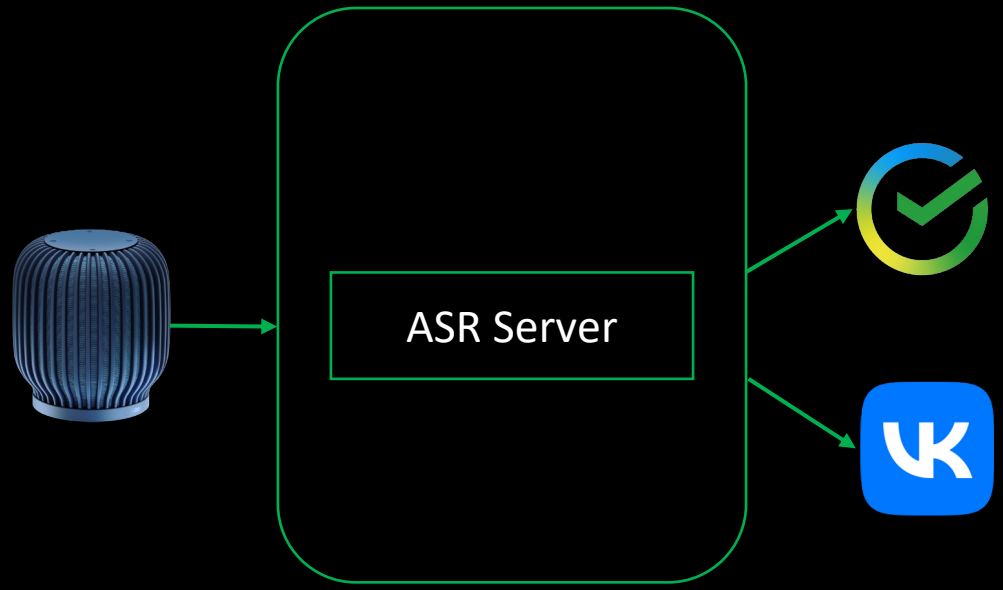
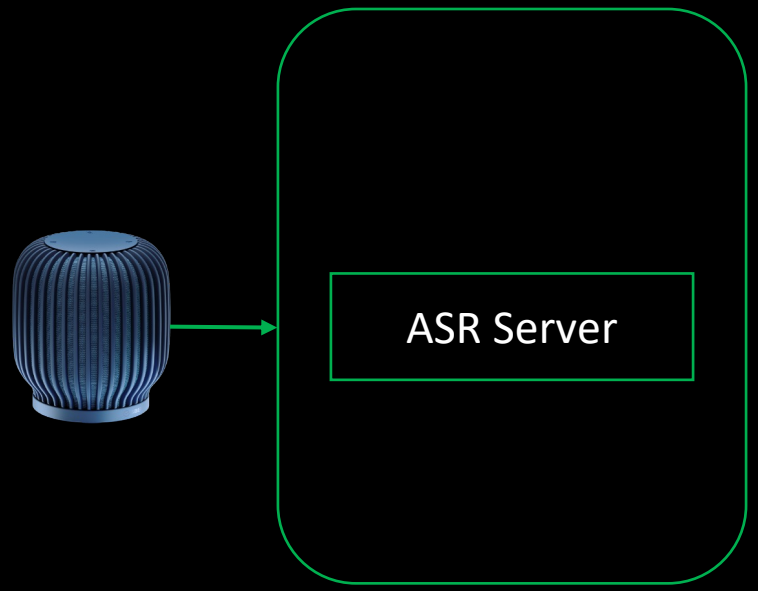


Keyword detection: on-device

Почему on-device?
- Конфиденциальность
- Вычислительные мощности



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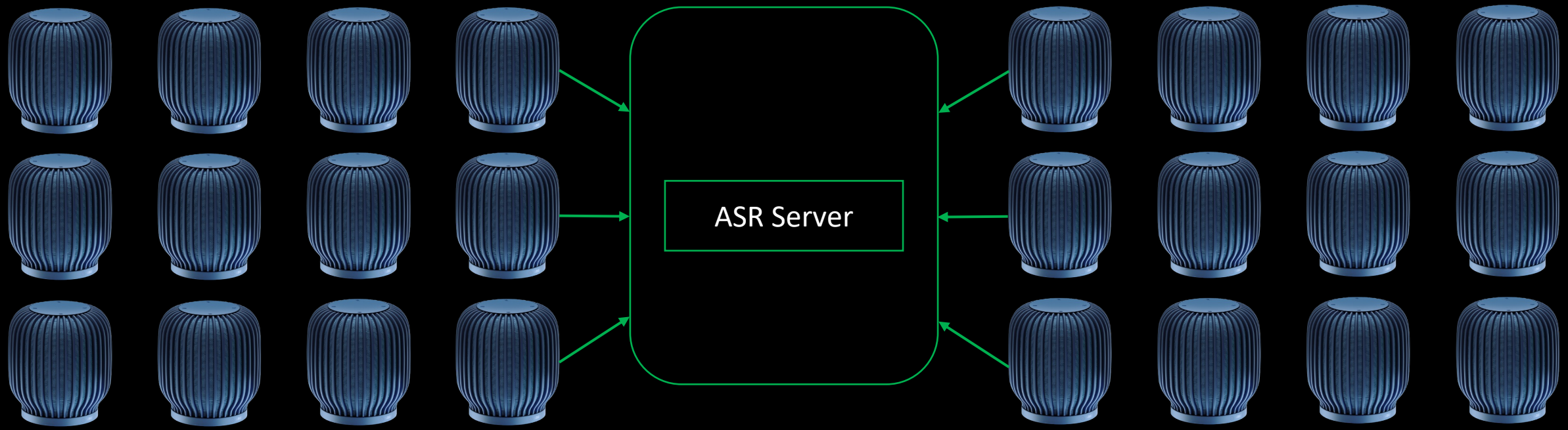
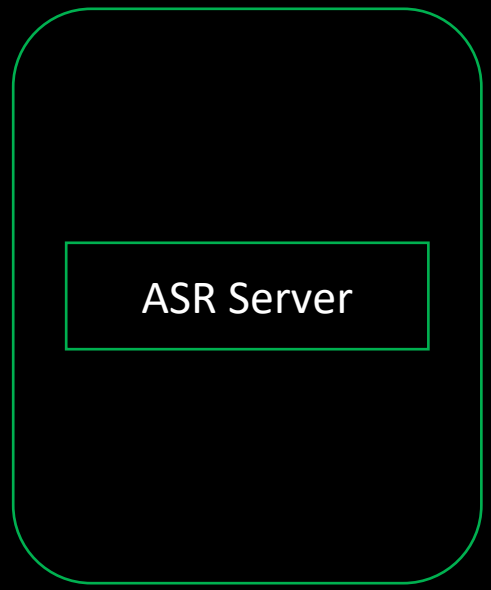
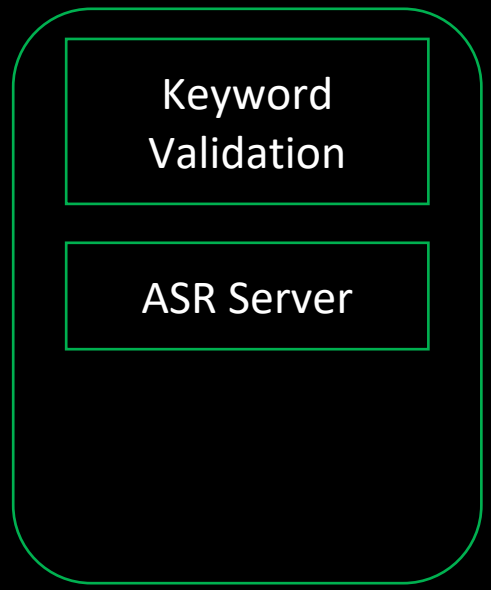


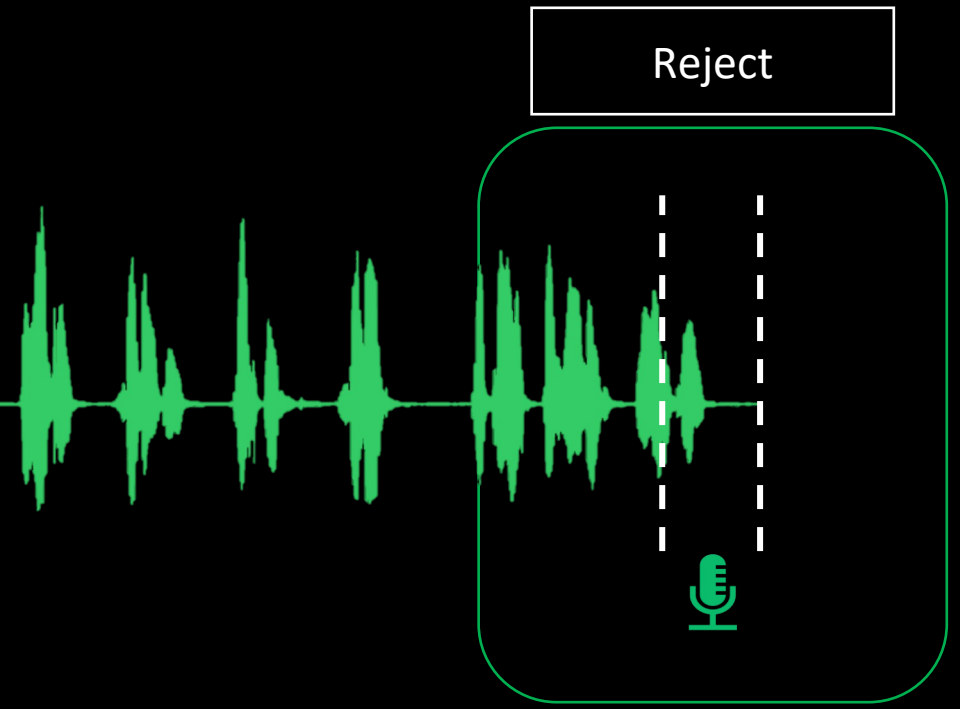
Keyword detection: cascade system

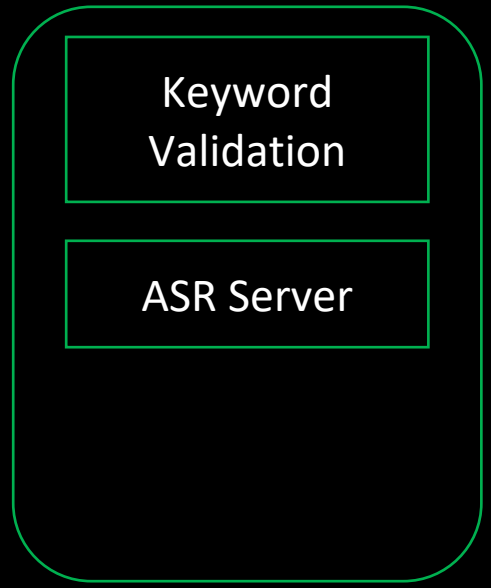


Keyword detection: cascade system

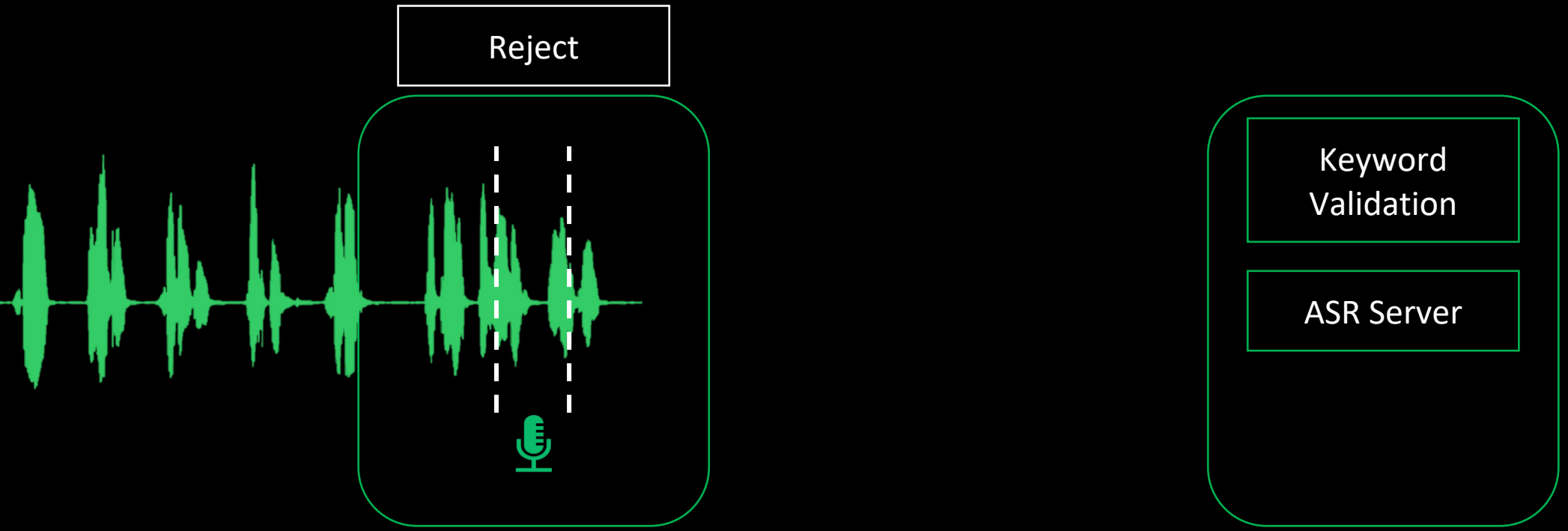


Keyword detection: cascade system

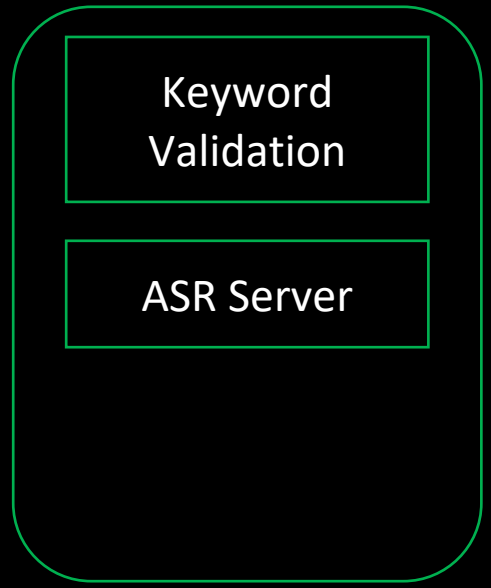




Keyword detection: cascade system



Keyword detection: cascade system



Keyword detection: cascade system

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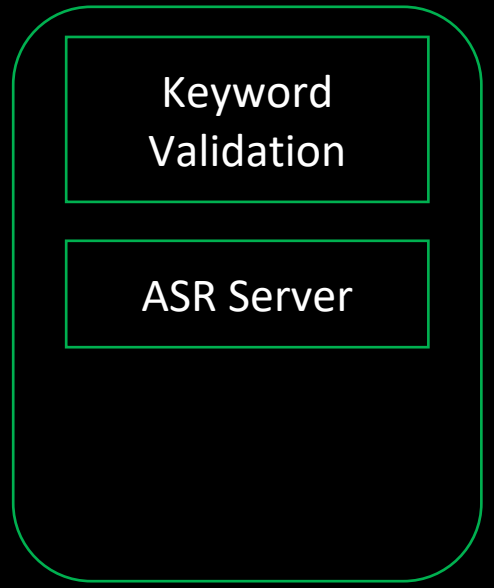

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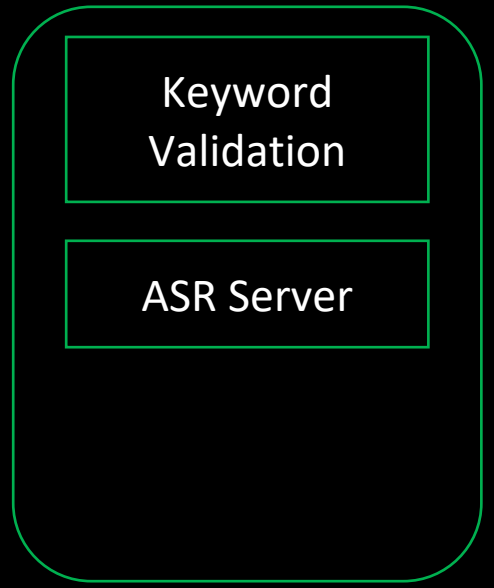
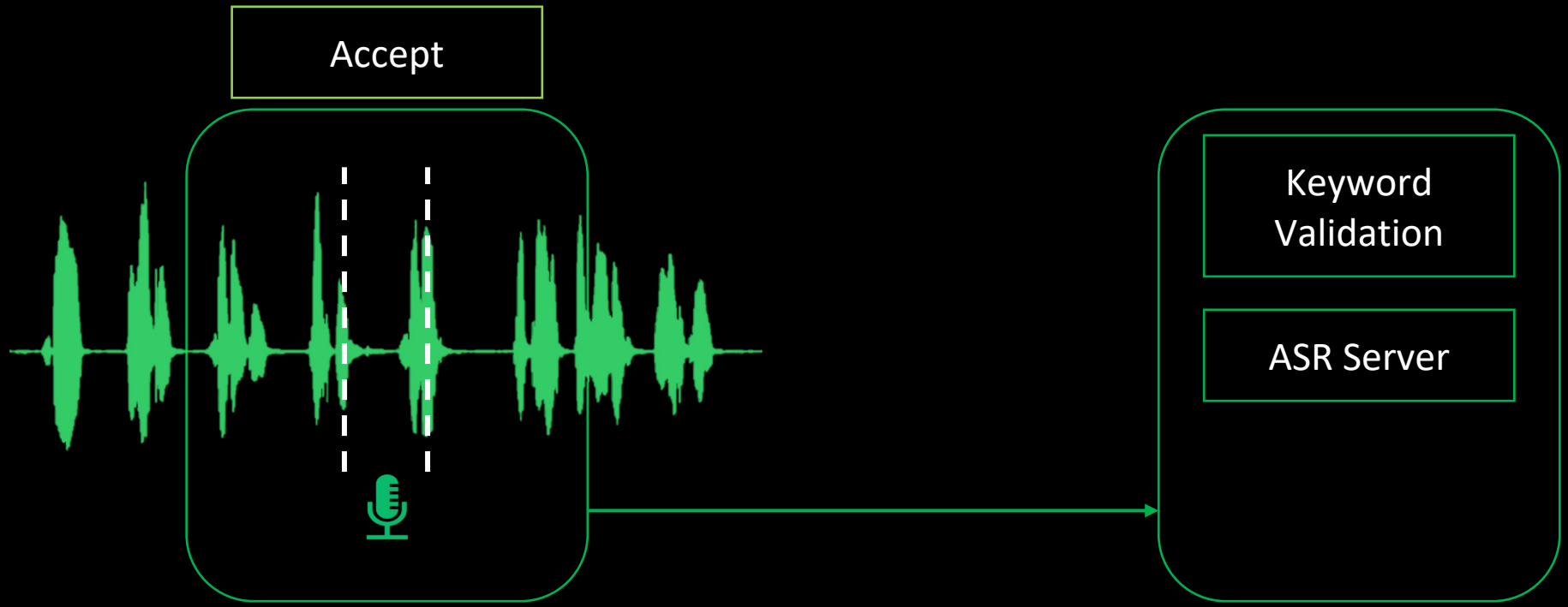
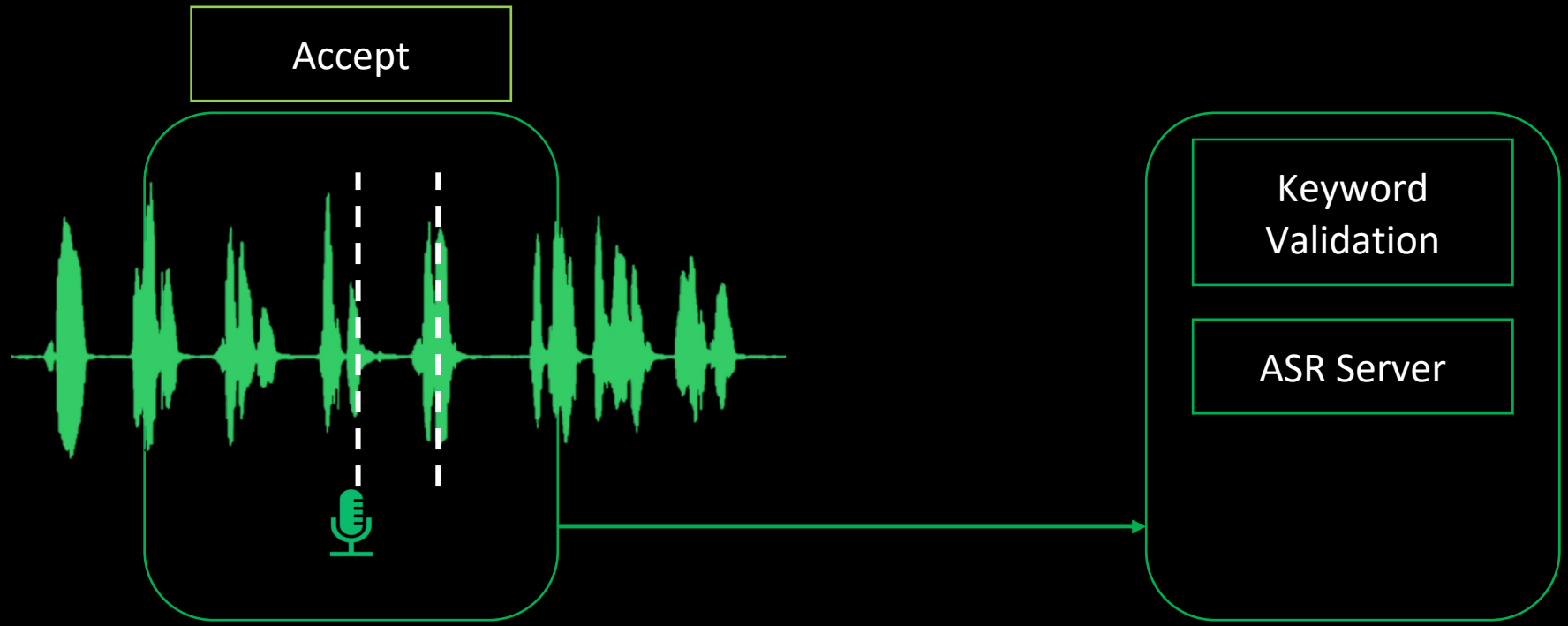


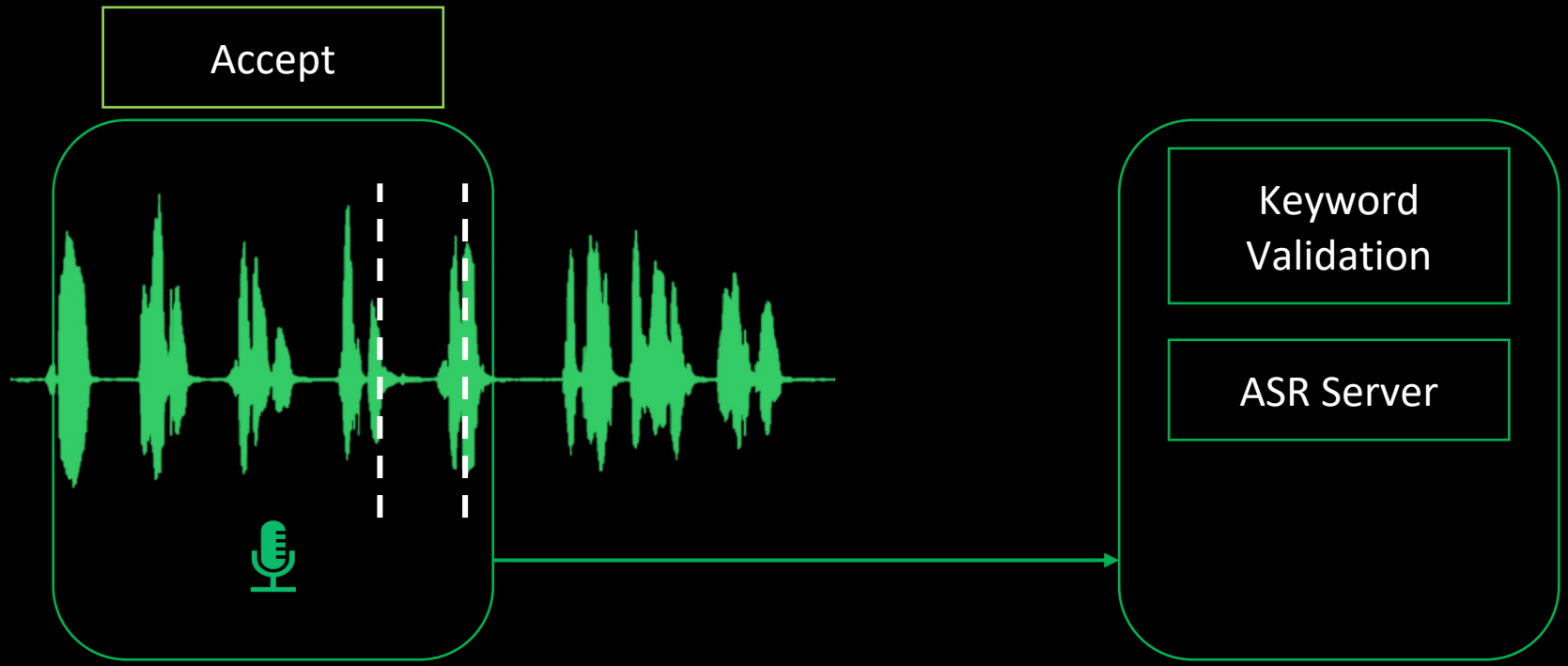
Keyword detection: cascade system



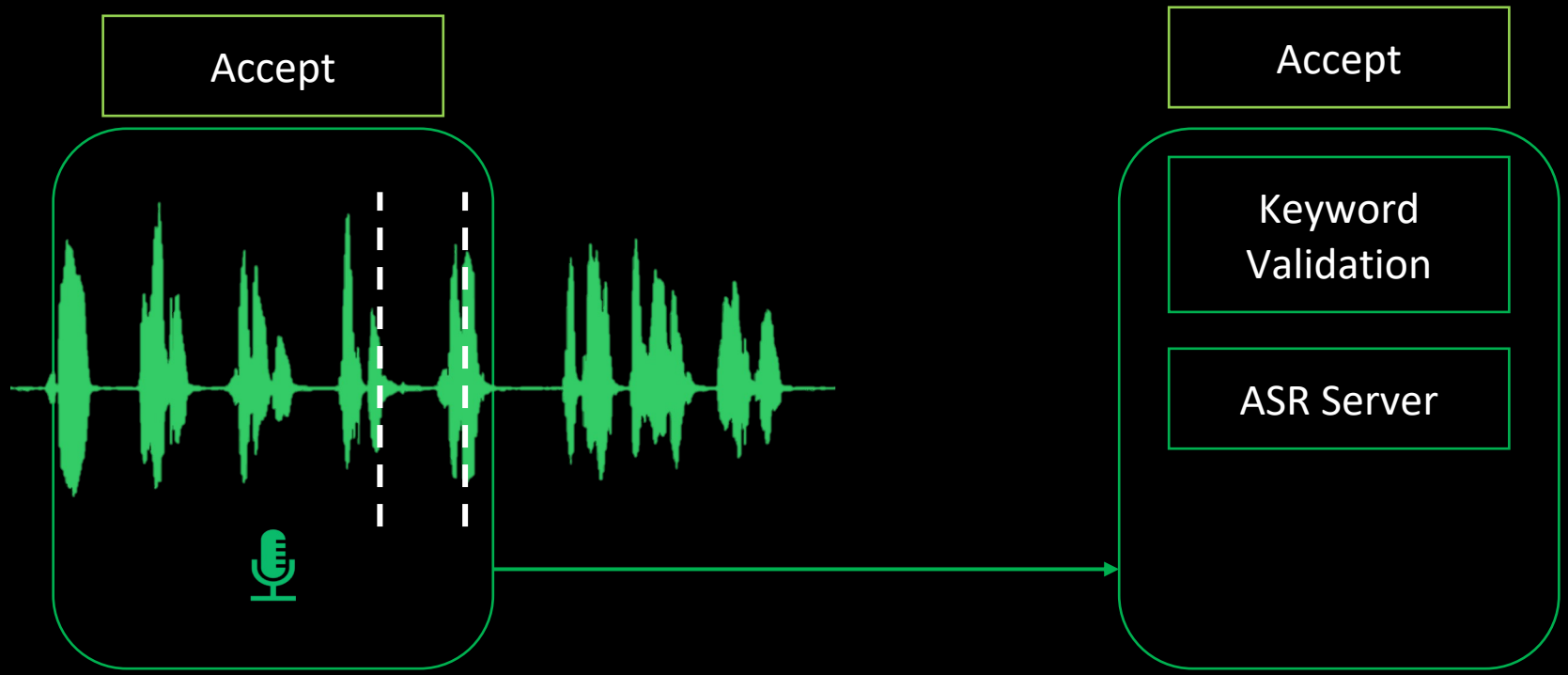
Keyword detection: cascade system



Keyword detection: cascade system



Keyword detection: cascade system



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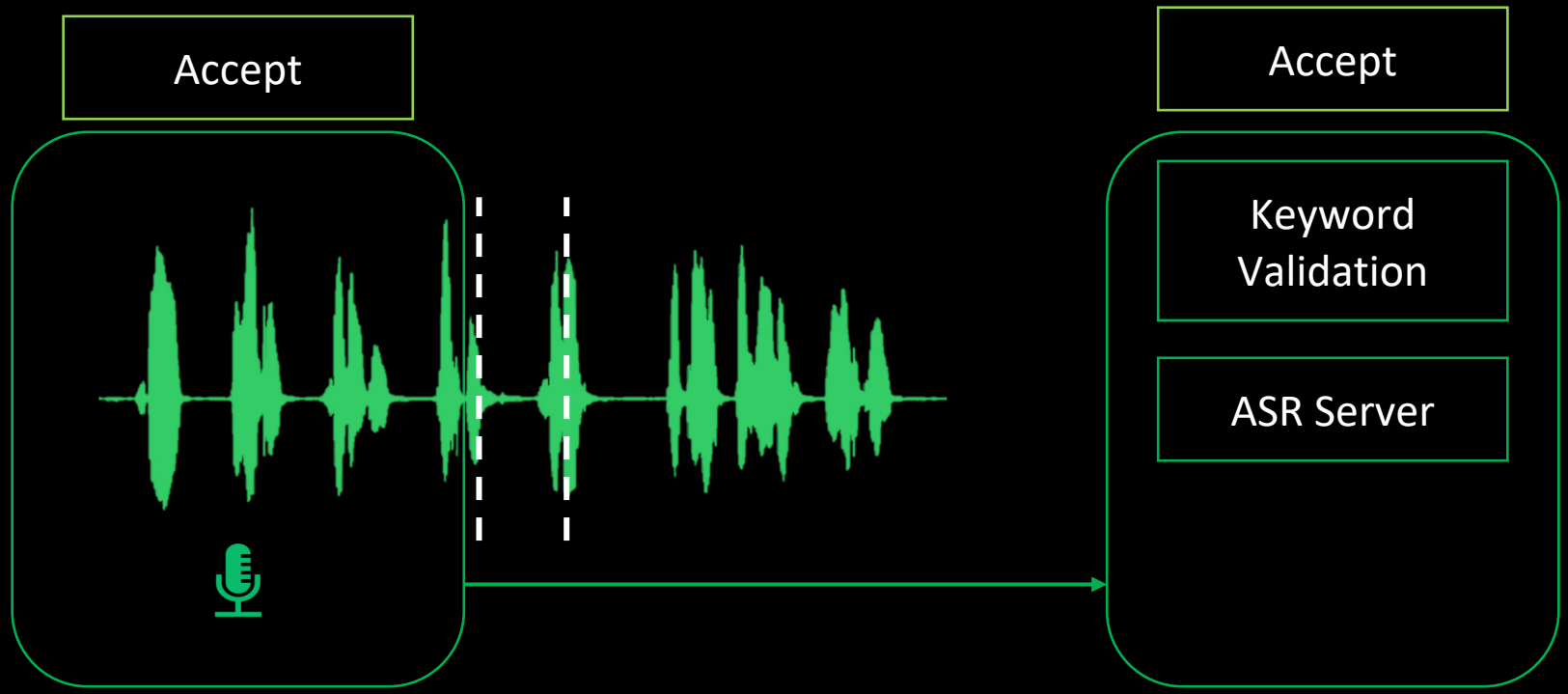
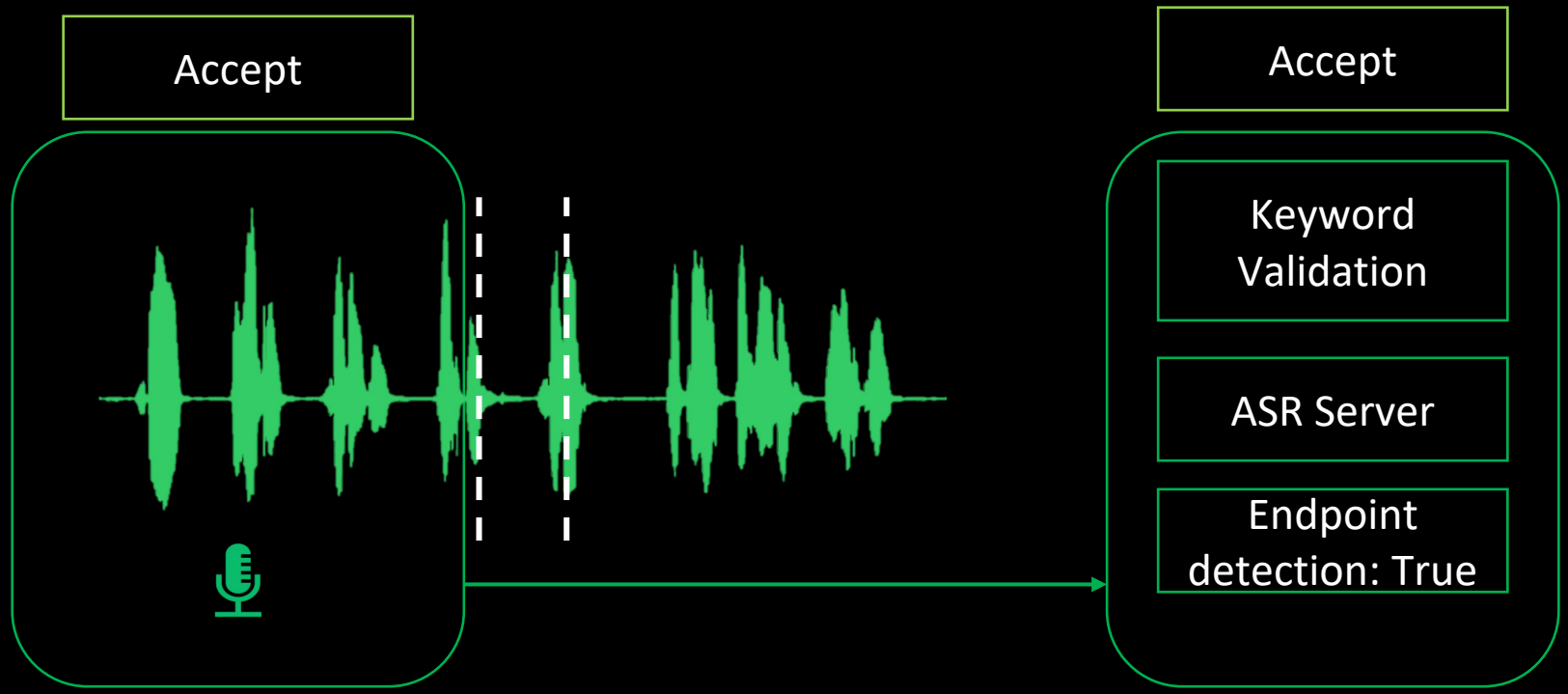
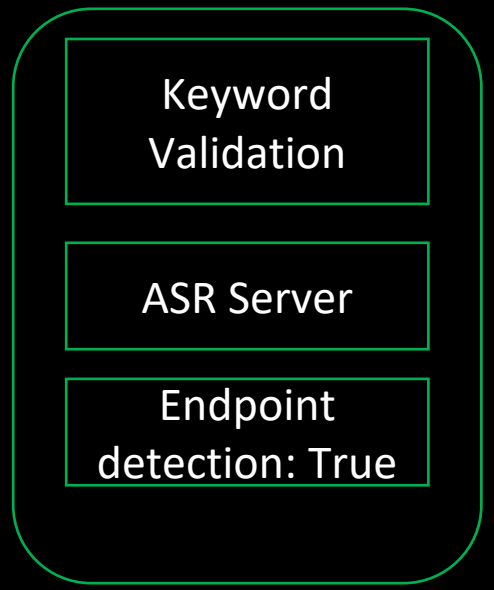


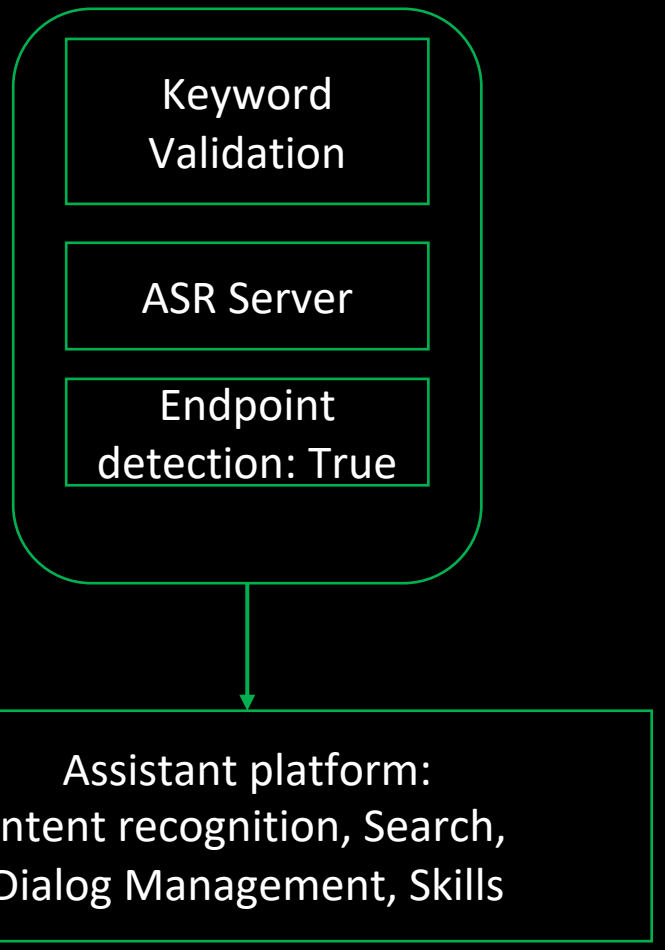
Keyword detection: cascade system



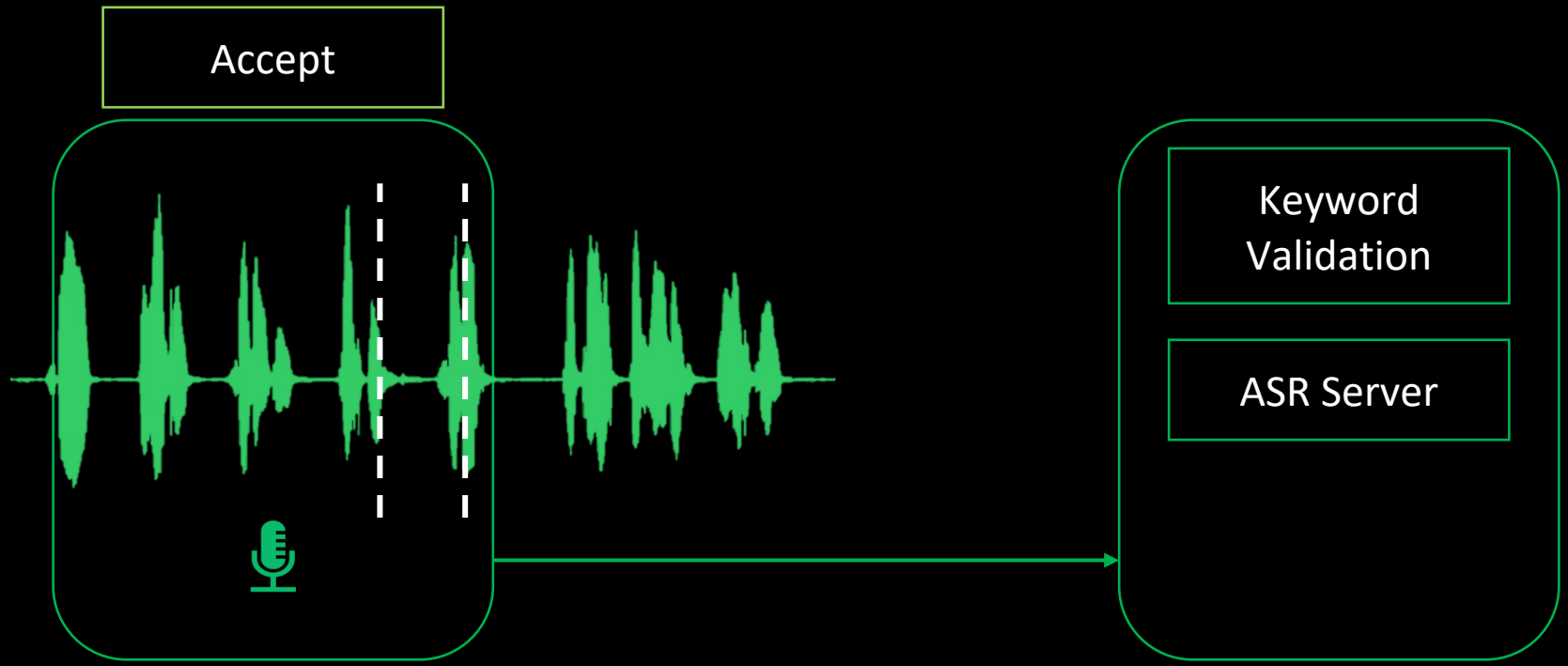
Keyword detection: cascade system



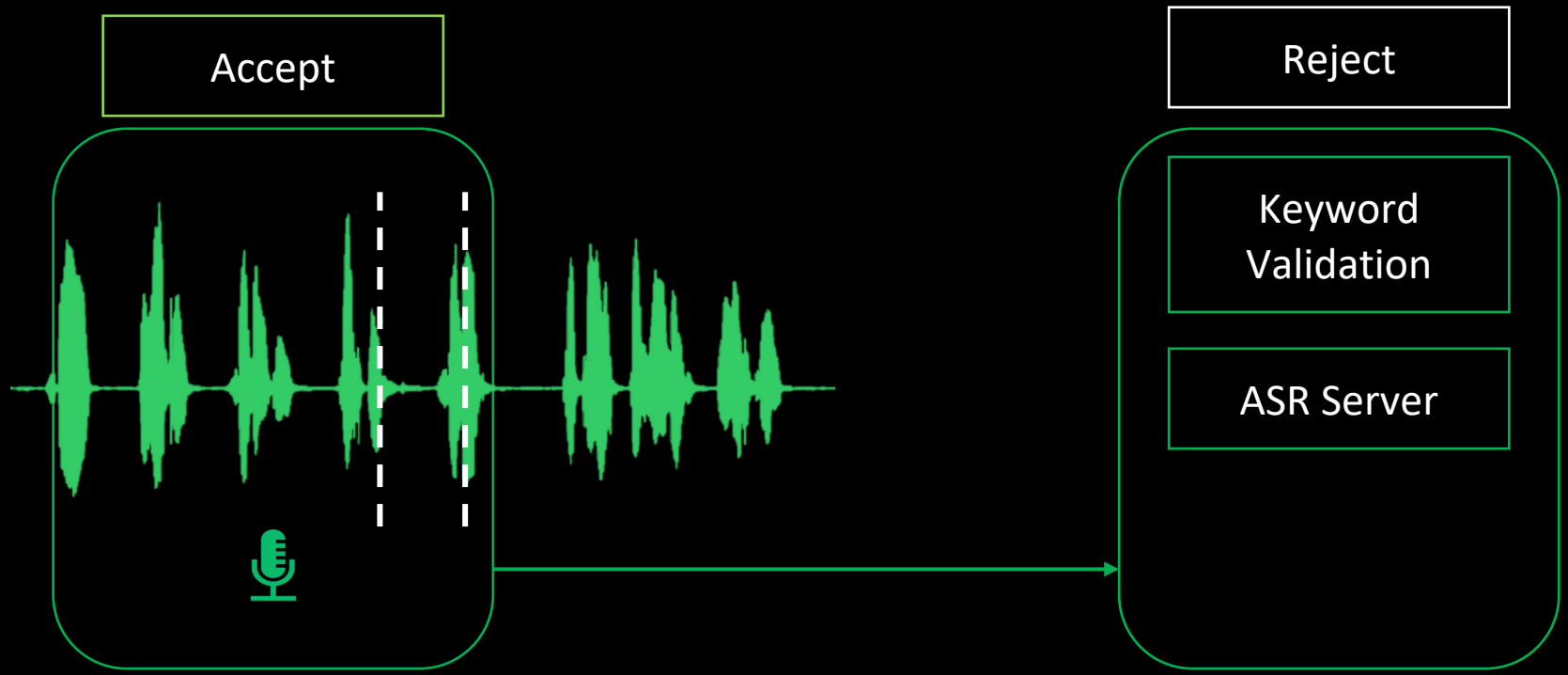
Keyword detection: cascade system



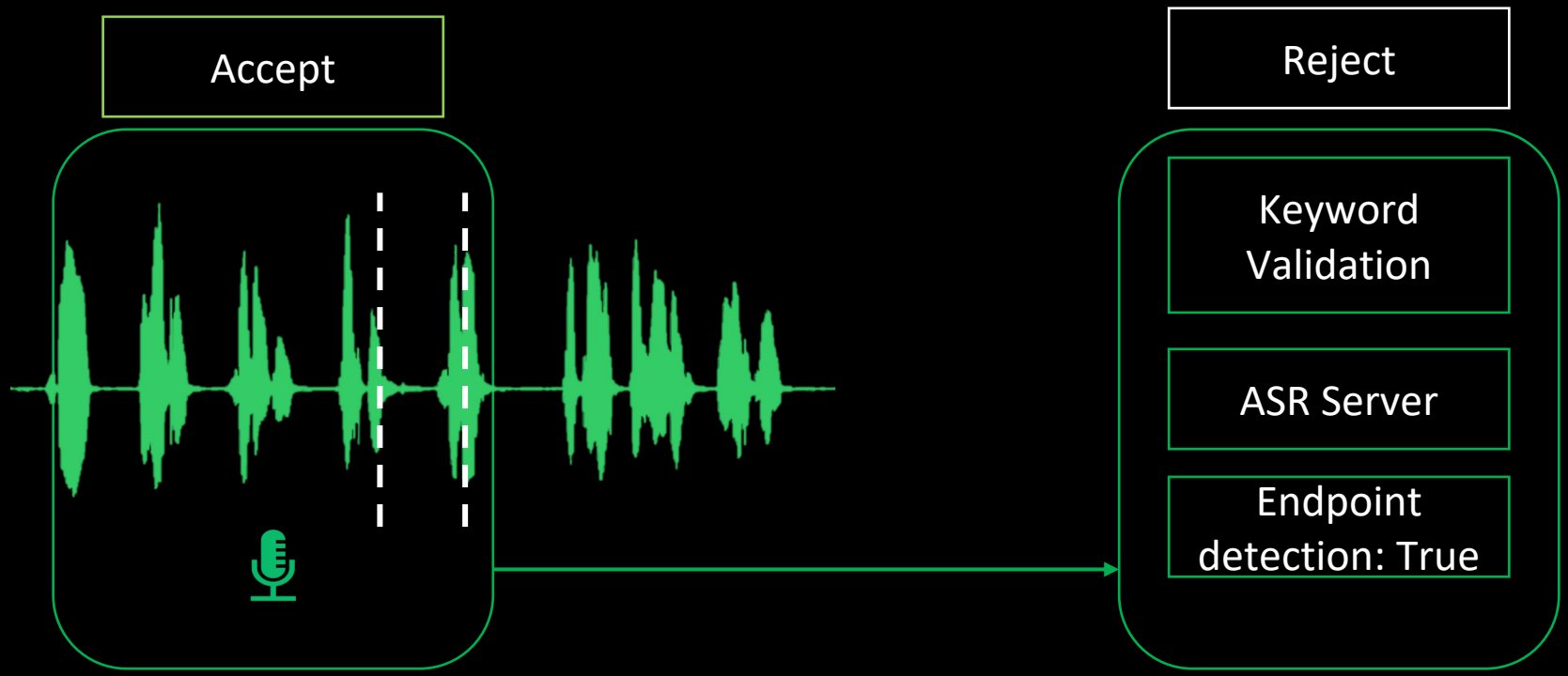
Keyword detection: cascade system



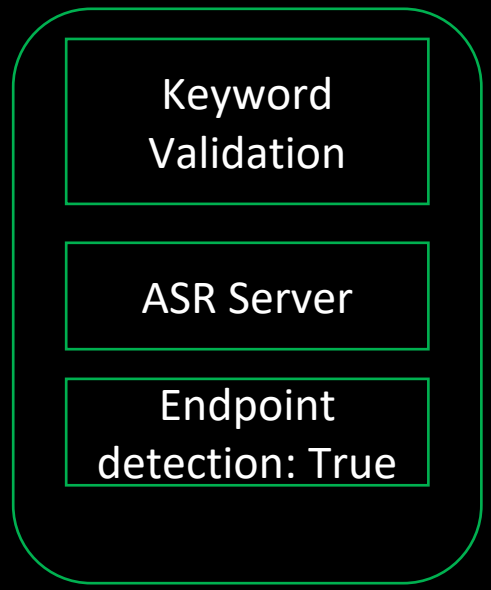
Keyword detection: cascade system



Keyword detection: cascade system



Keyword detection: cascade system



Keyword detection: cascade system

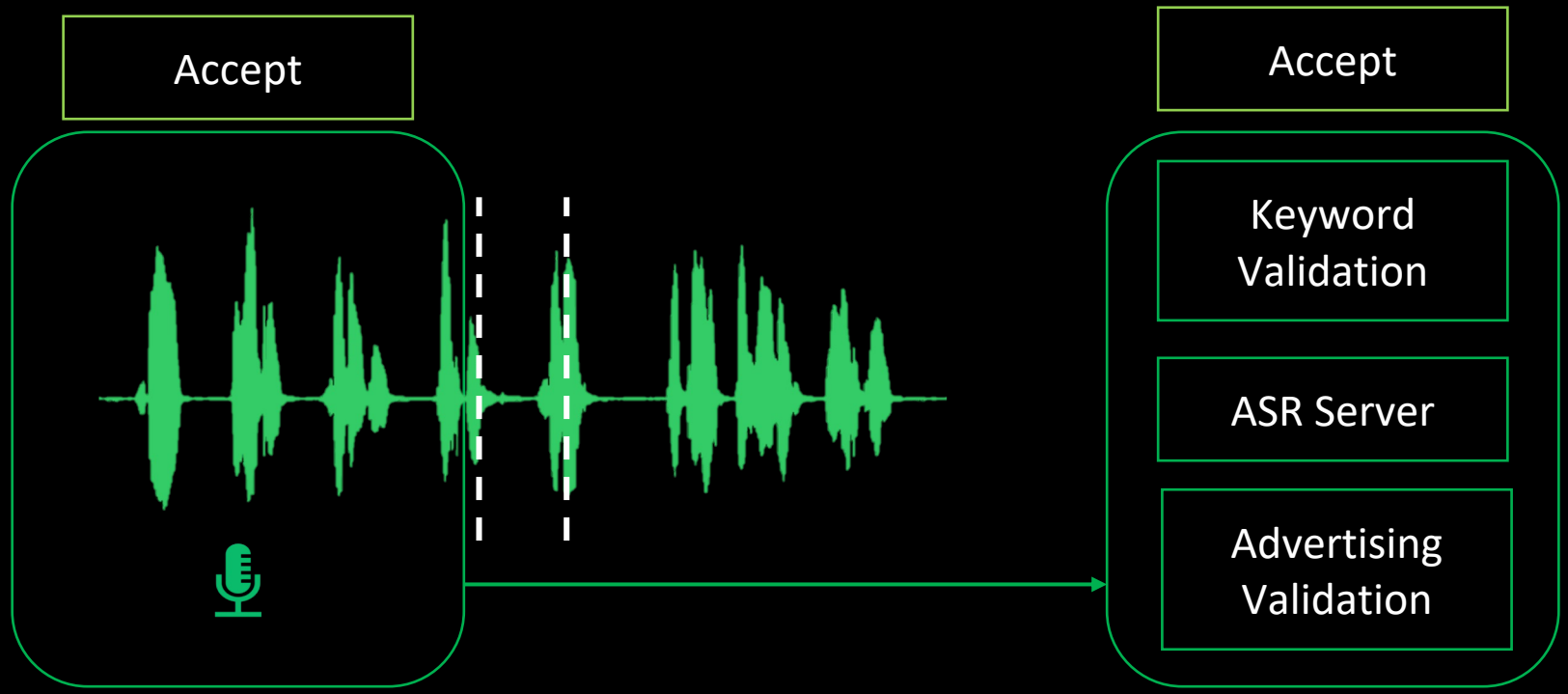
Преимущества:
- Высокая точность
- Гибкость системы

Недостатки:
- Дополнительные вычислительные расходы

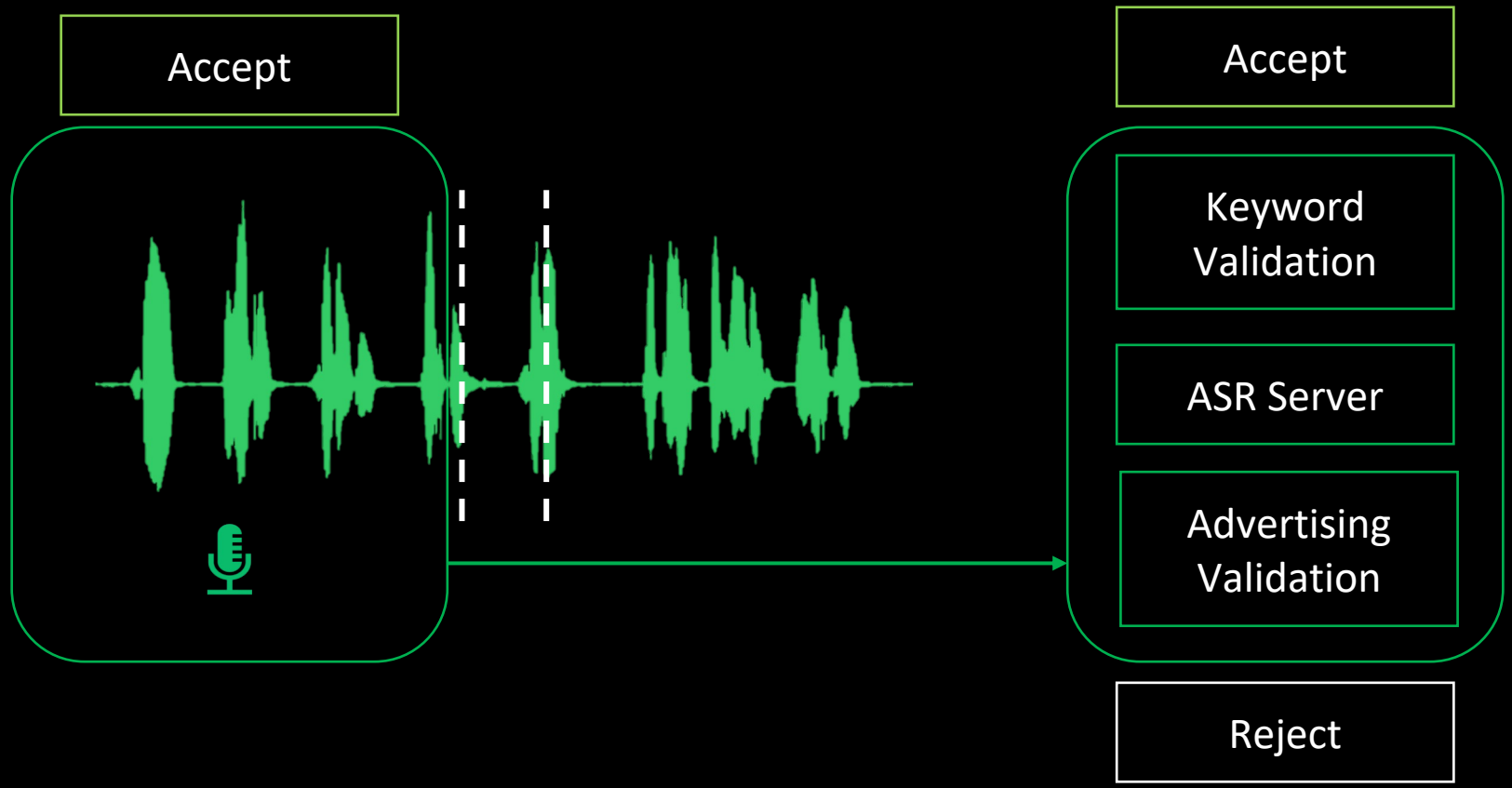
Keyword detection: complex cascade system

Что может быть еще?
- Валидация рекламы

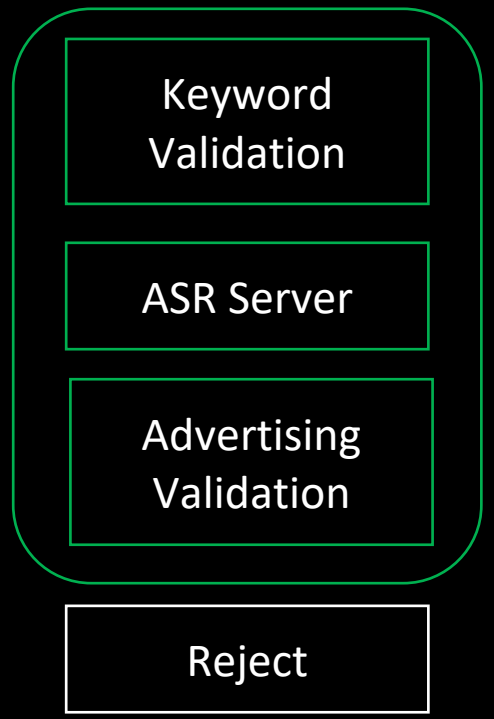
Keyword detection: complex cascade system



Keyword detection: complex cascade system

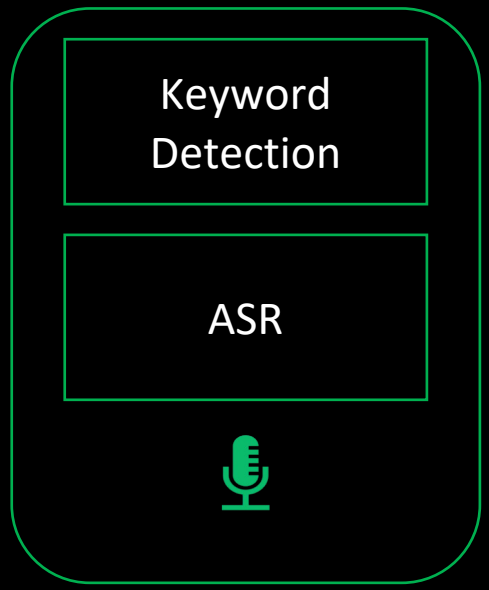


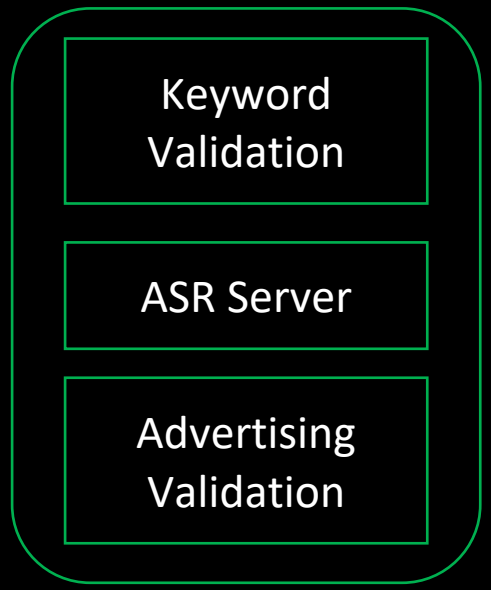
Keyword detection: complex cascade system



Keyword detection: complex cascade system

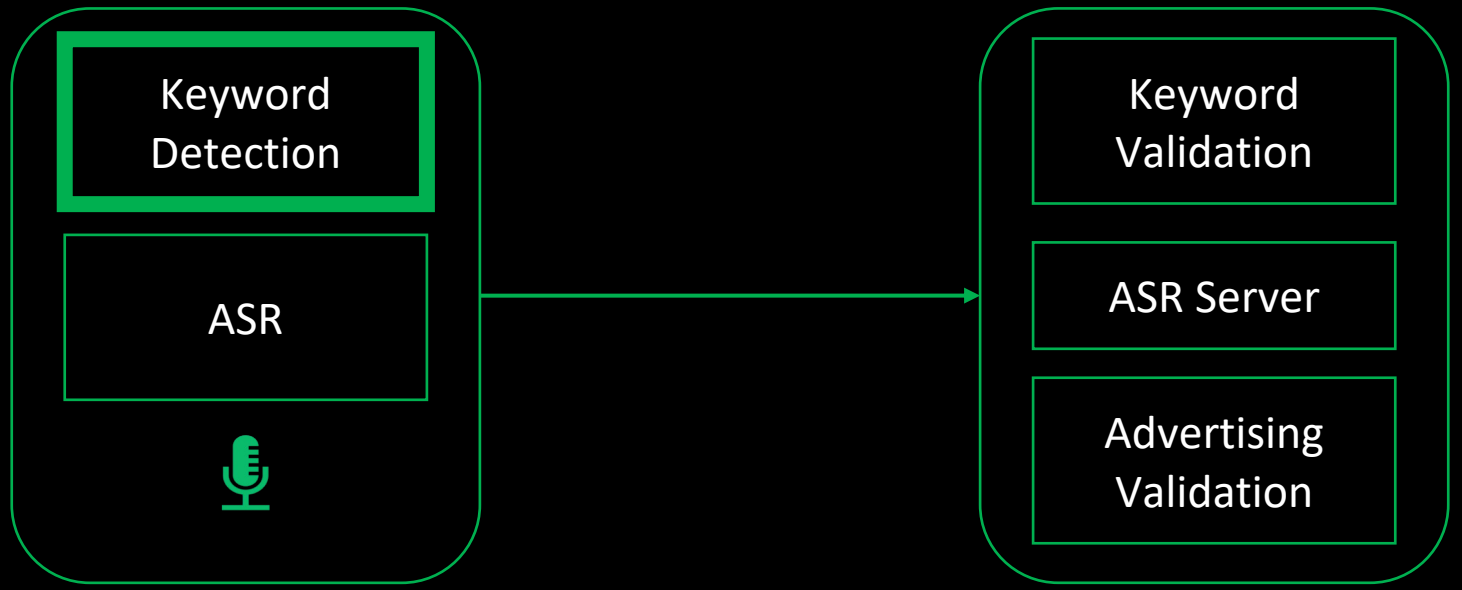
Что может быть еще?
- Быстрые команды, habr





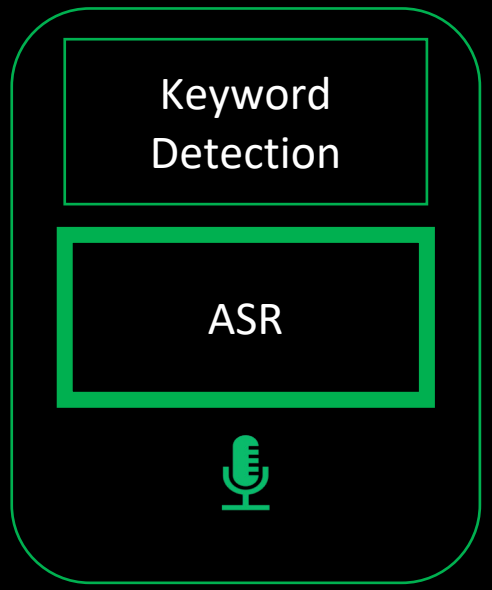
Keyword detection: complex cascade system

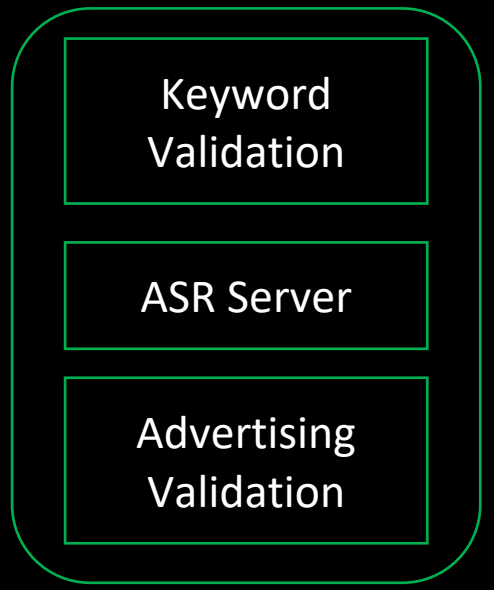
Что может быть еще?
- Быстрые команды, habr



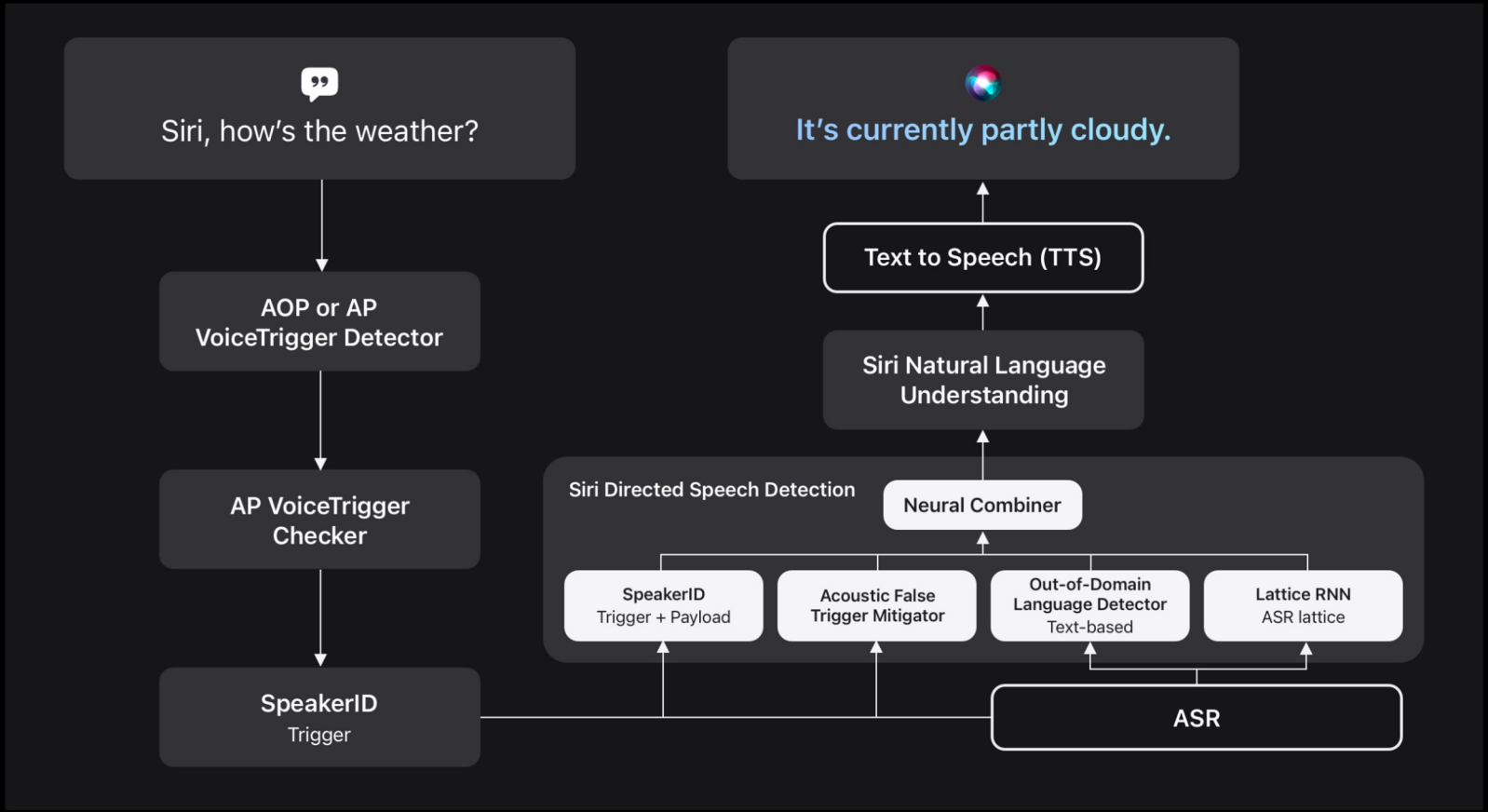
Keyword detection: complex cascade system

Что может быть еще?
- Быстрые команды, habr





Keyword detection: complex cascade system



Voice Trigger System for Siri: Apple, 2023

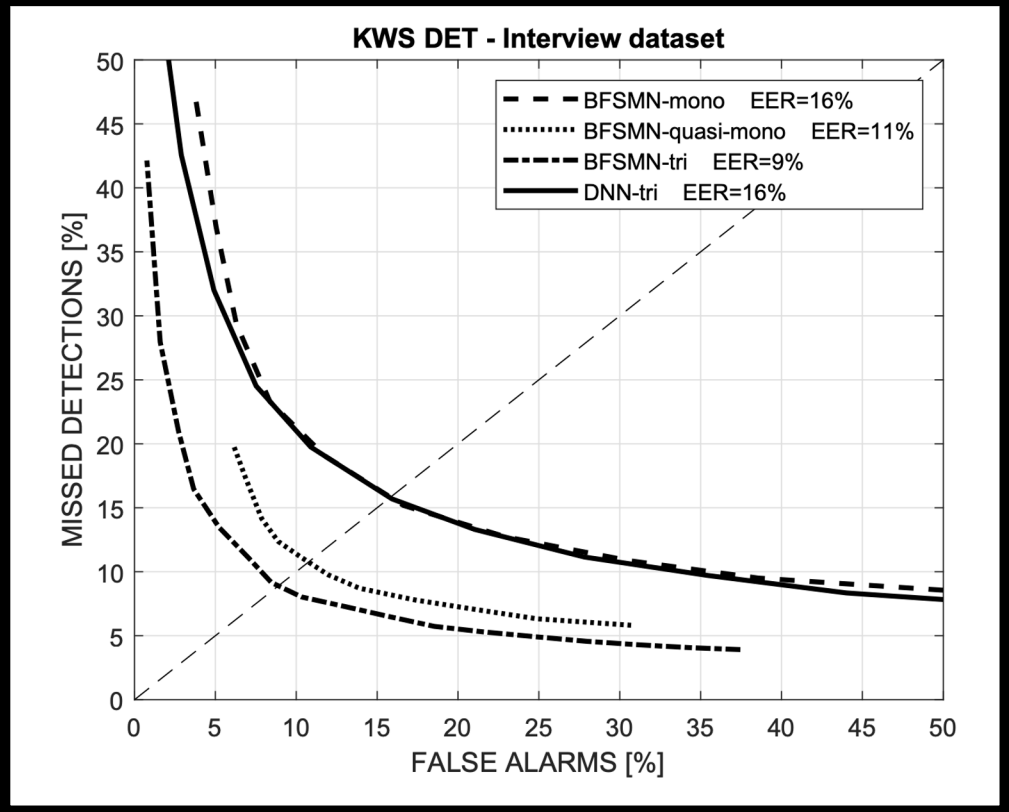
Keyword detection: метрики

FAR: False (Activation / Accepts / Alarm) Rate
- FAR = FP / (FP + TN)

FRR: False Rejects Rate
- FRR = FN / (FN + TP)

FAh: False Accepts per hour
- Количество ложных срабатываний в час

Detection Error Tradeoff



User perceived latency

Скорость отклика
- Быстрое выполнение команд, без задержек и пауз

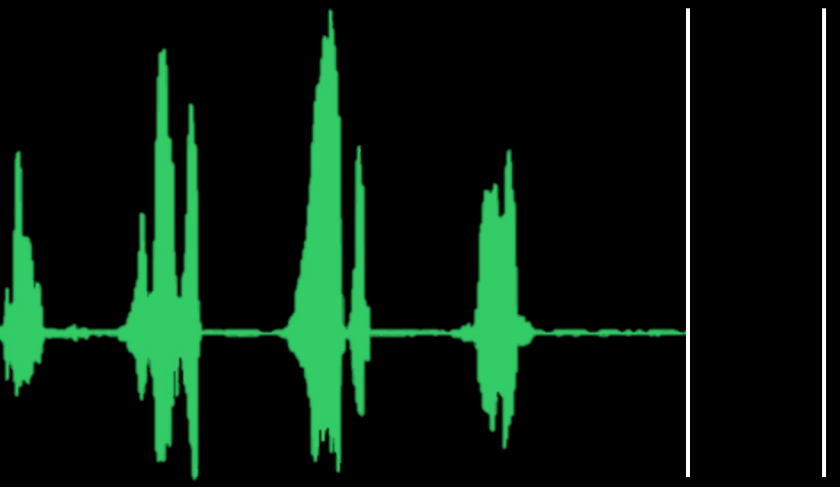
User perceived latency – метрика, отражающая воспринимаемое пользователем время задержки между действием и реакцией системы.

В нашем случае можем выделить два примера:
- Произношение активационной фразы <-> активация колонки
- Произношение голосового запроса <-> получение ответа

Endpoint detection

Основная задача в рамках Voice Assistant Pipeline
- Определение конца голосового запроса пользователя для завершения приема аудиосигнала и начала подготовки ответа

Endpoint detection



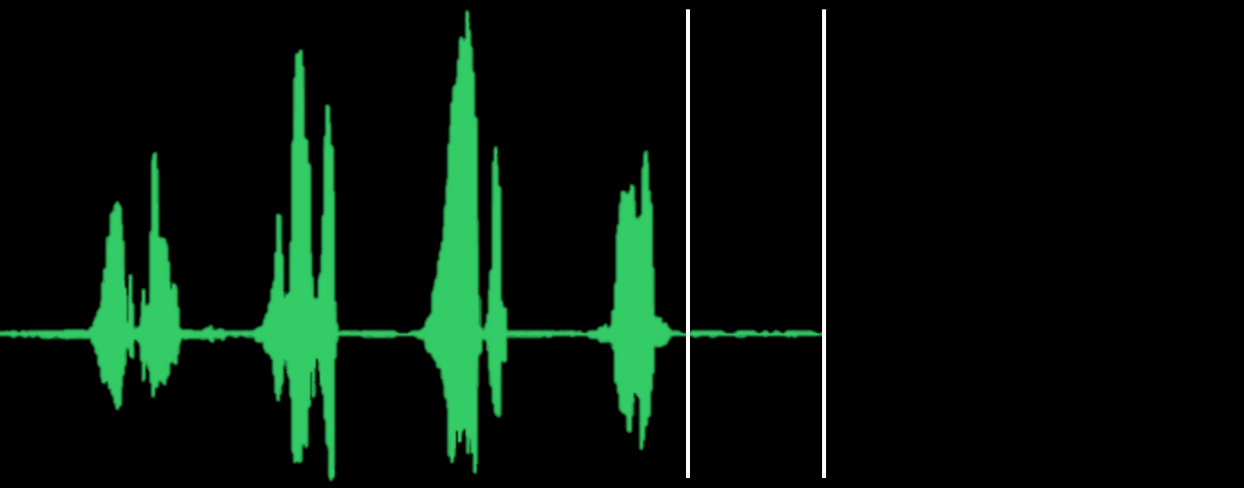
0 < x < 1

100ms

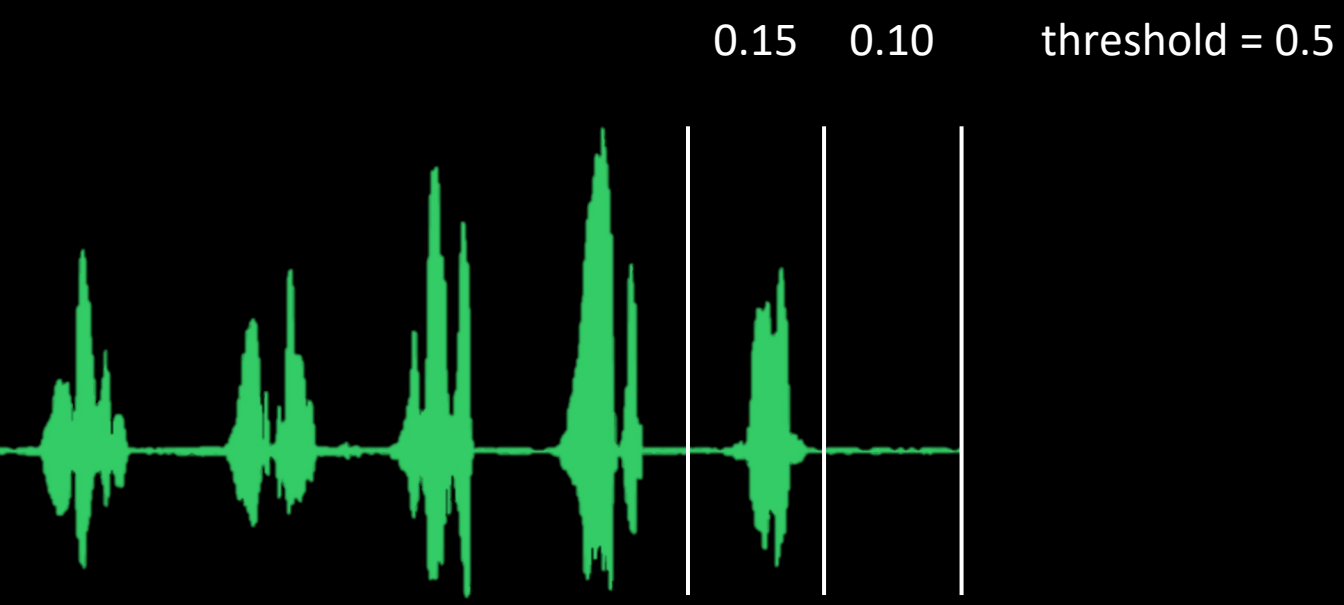
threshold

1 – endpoint: true
0 – endpoint: false

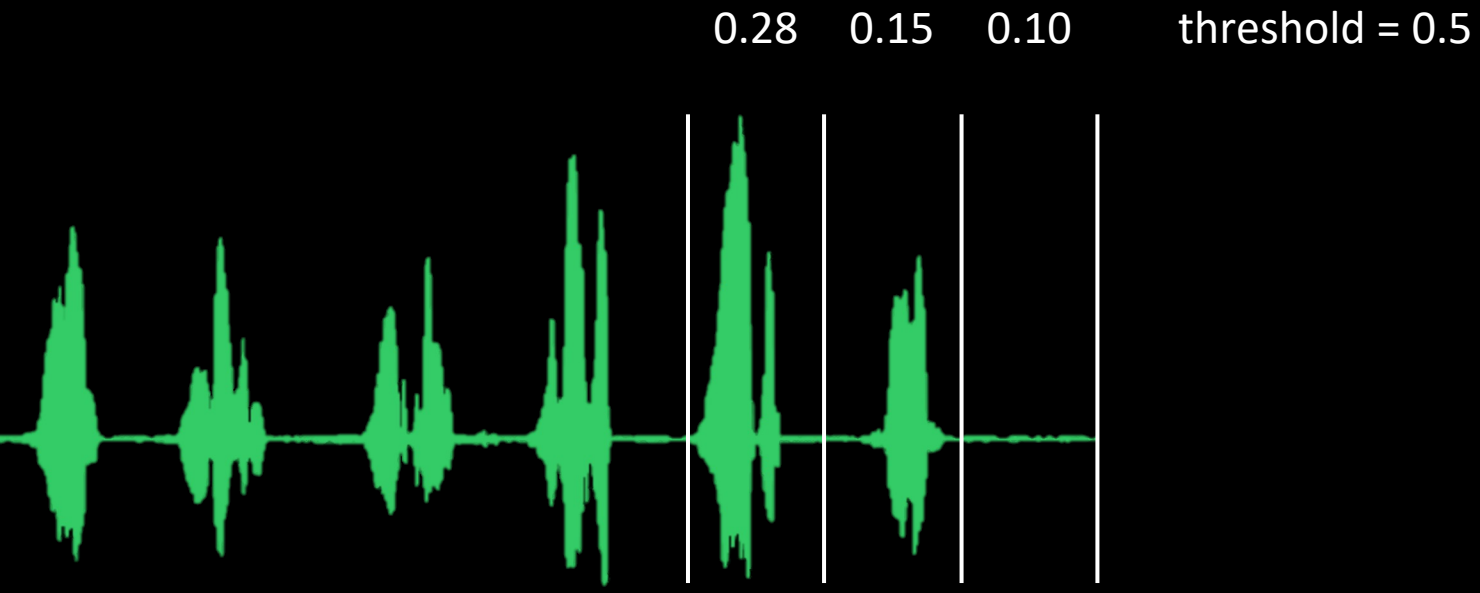
Endpoint detection



Endpoint detection

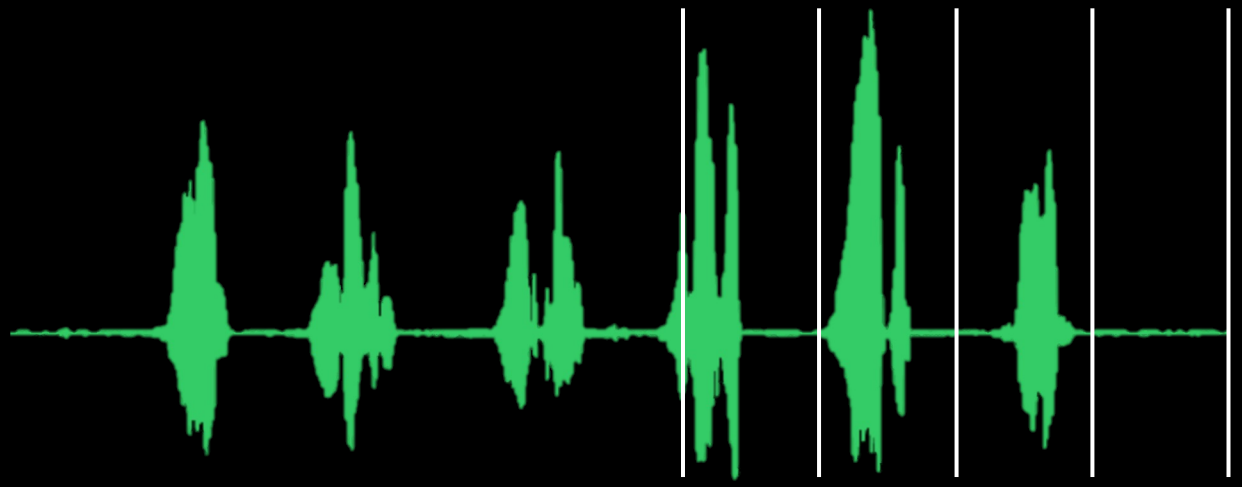


Endpoint detection

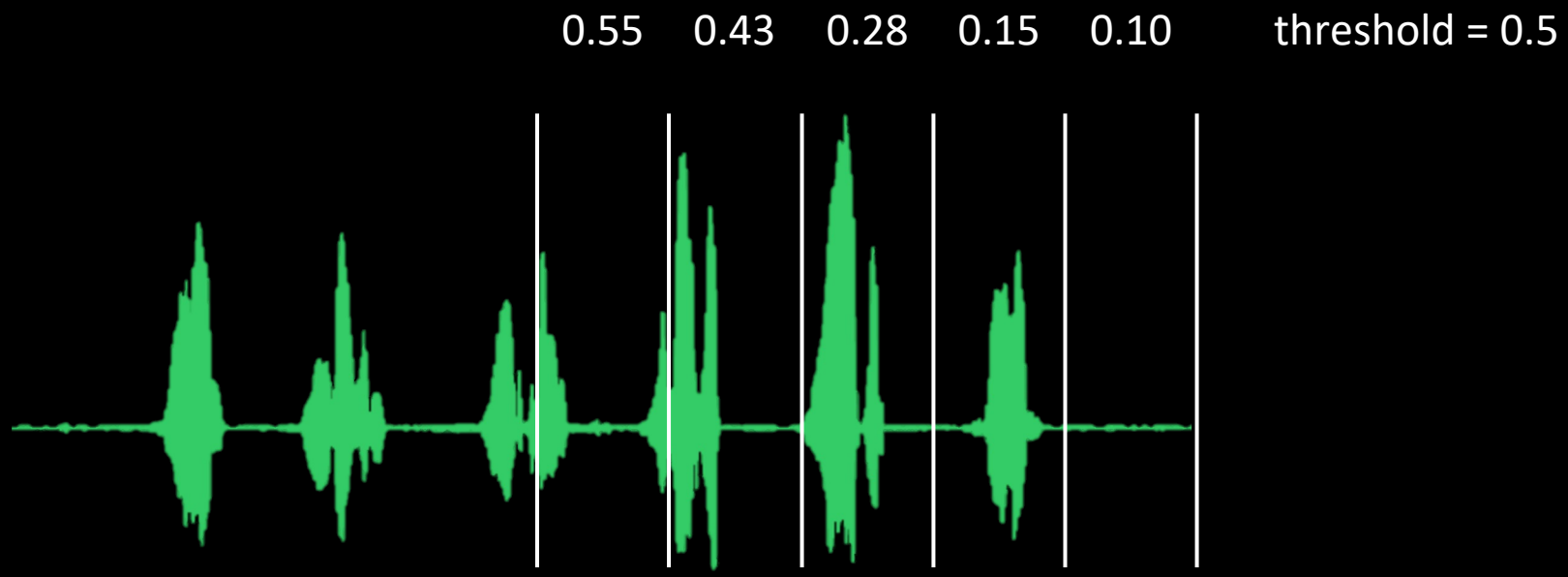


Endpoint detection

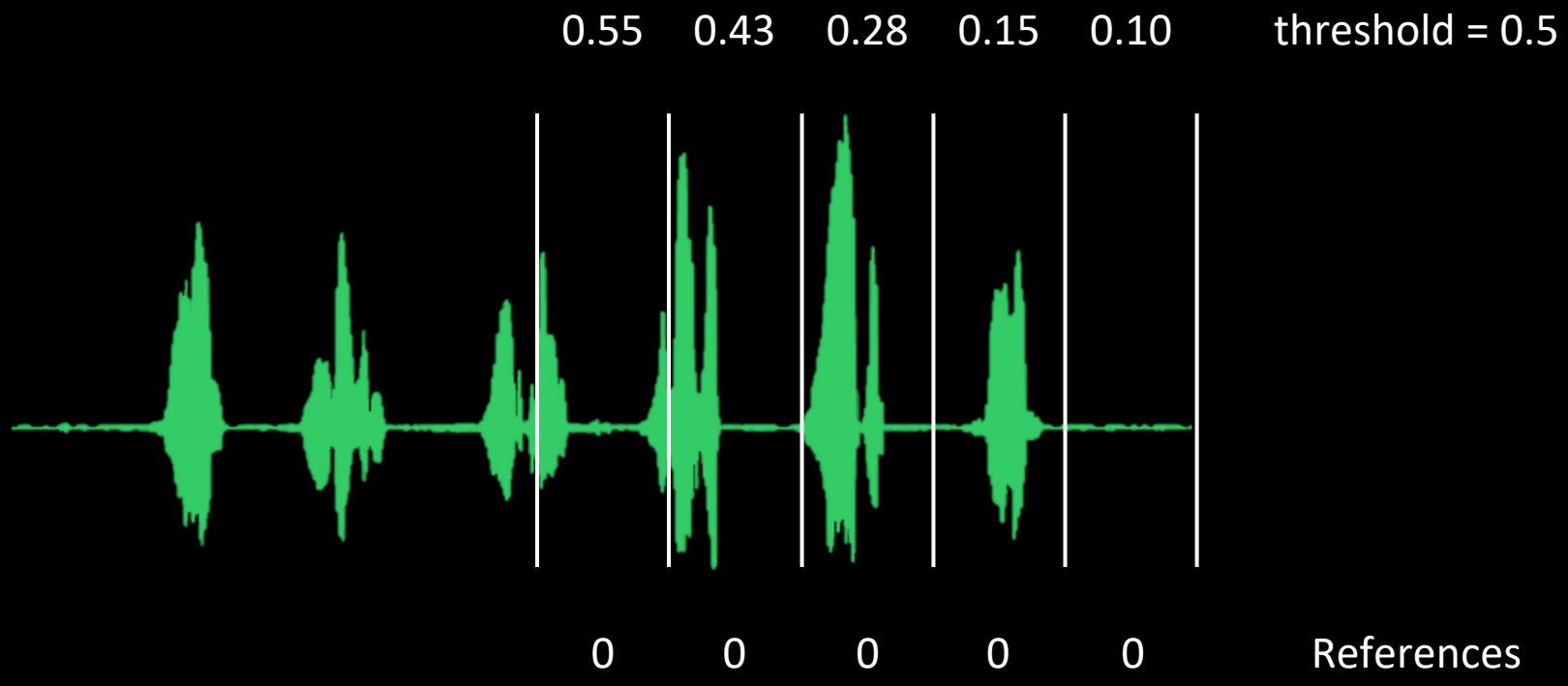
0.43 0.28 0.15 0.10 threshold = 0.5



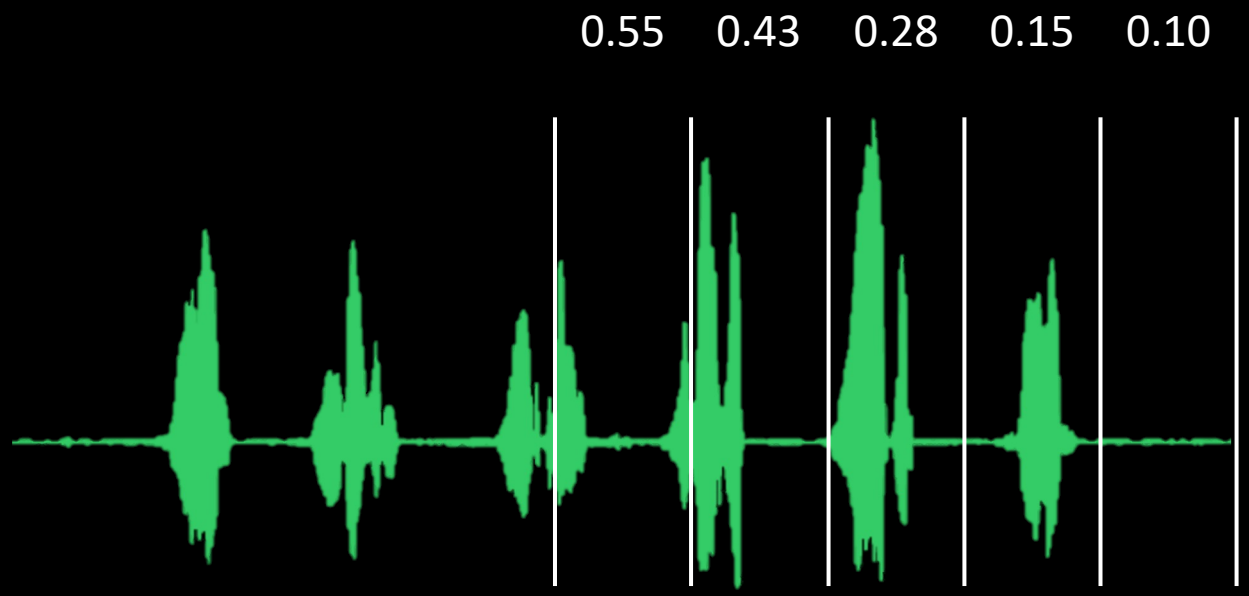
Endpoint detection



Endpoint detection

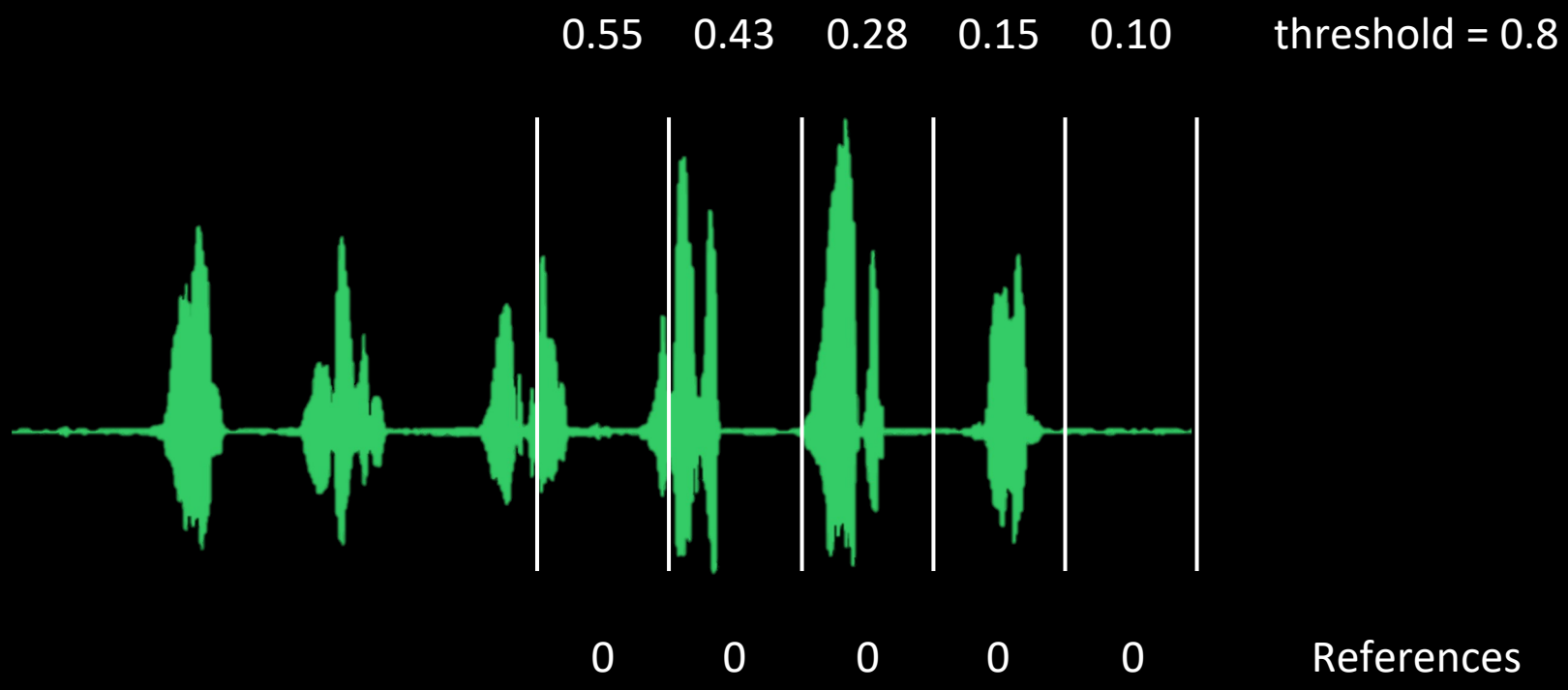


Endpoint detection

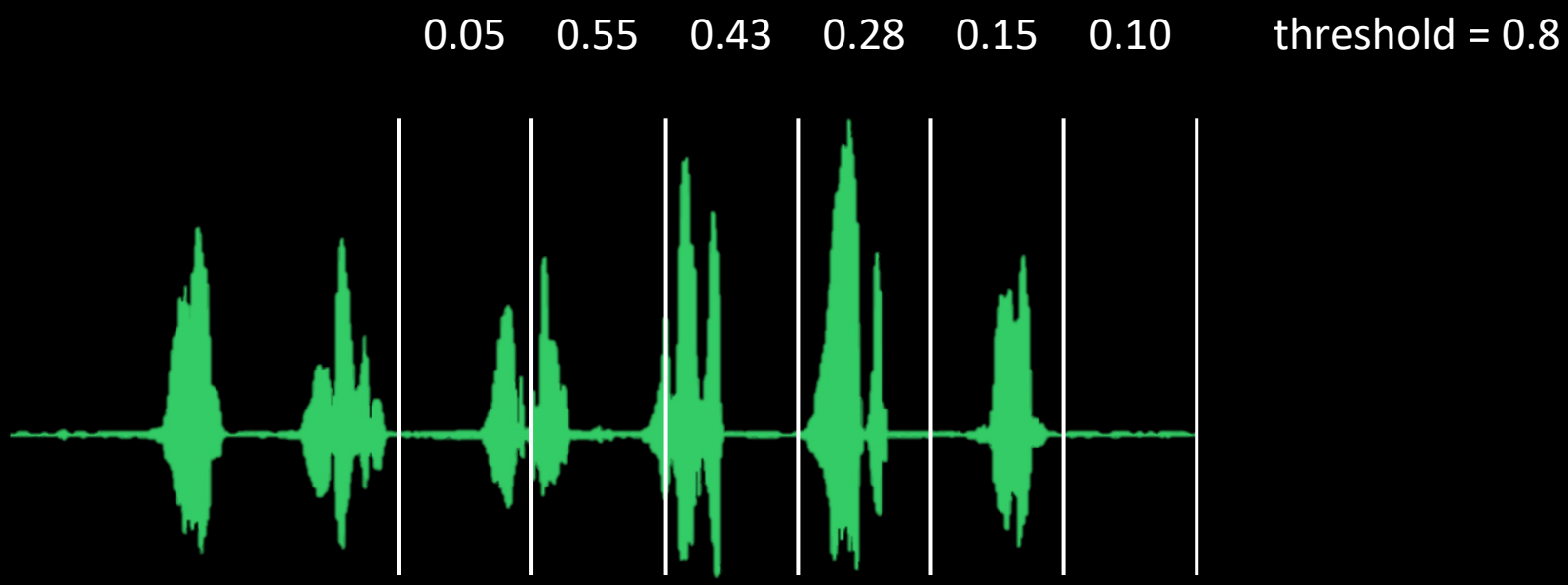


Early activation

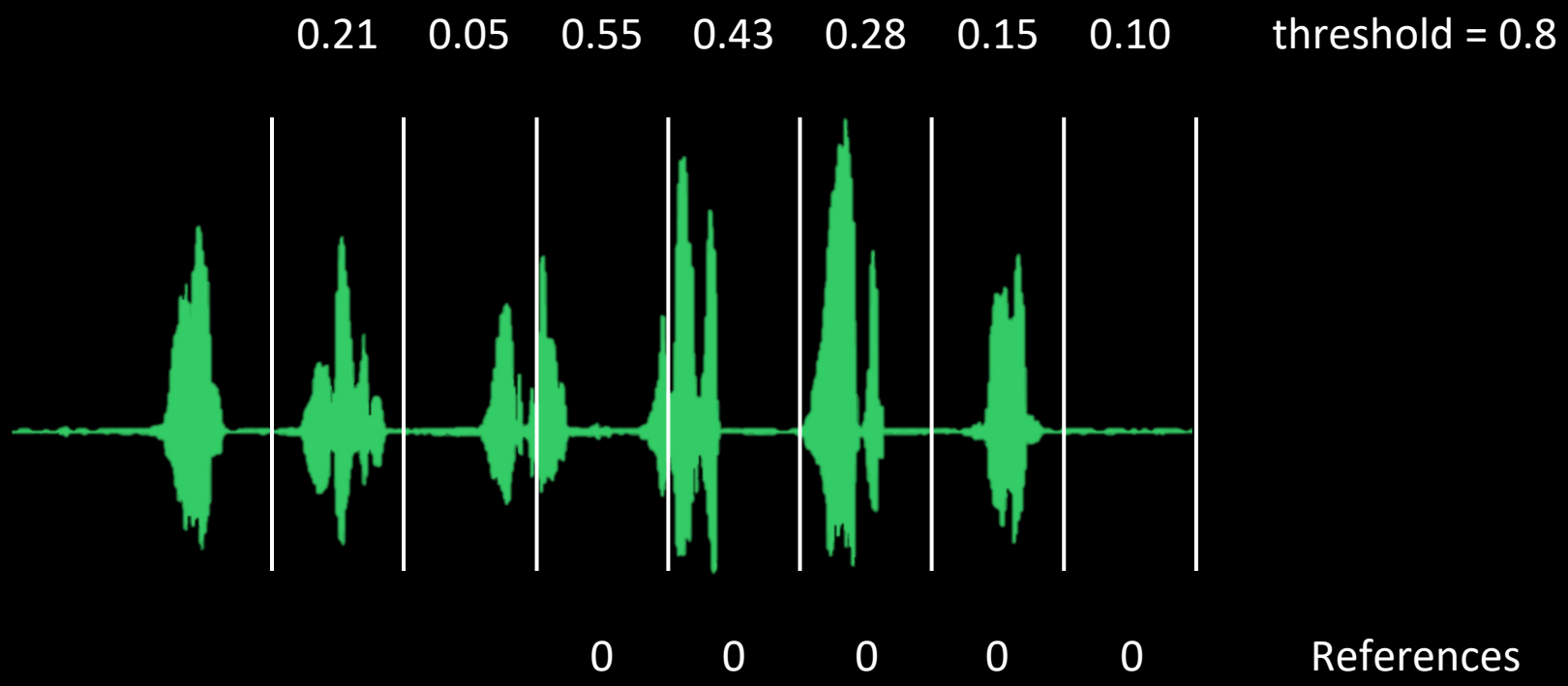
Endpoint detection



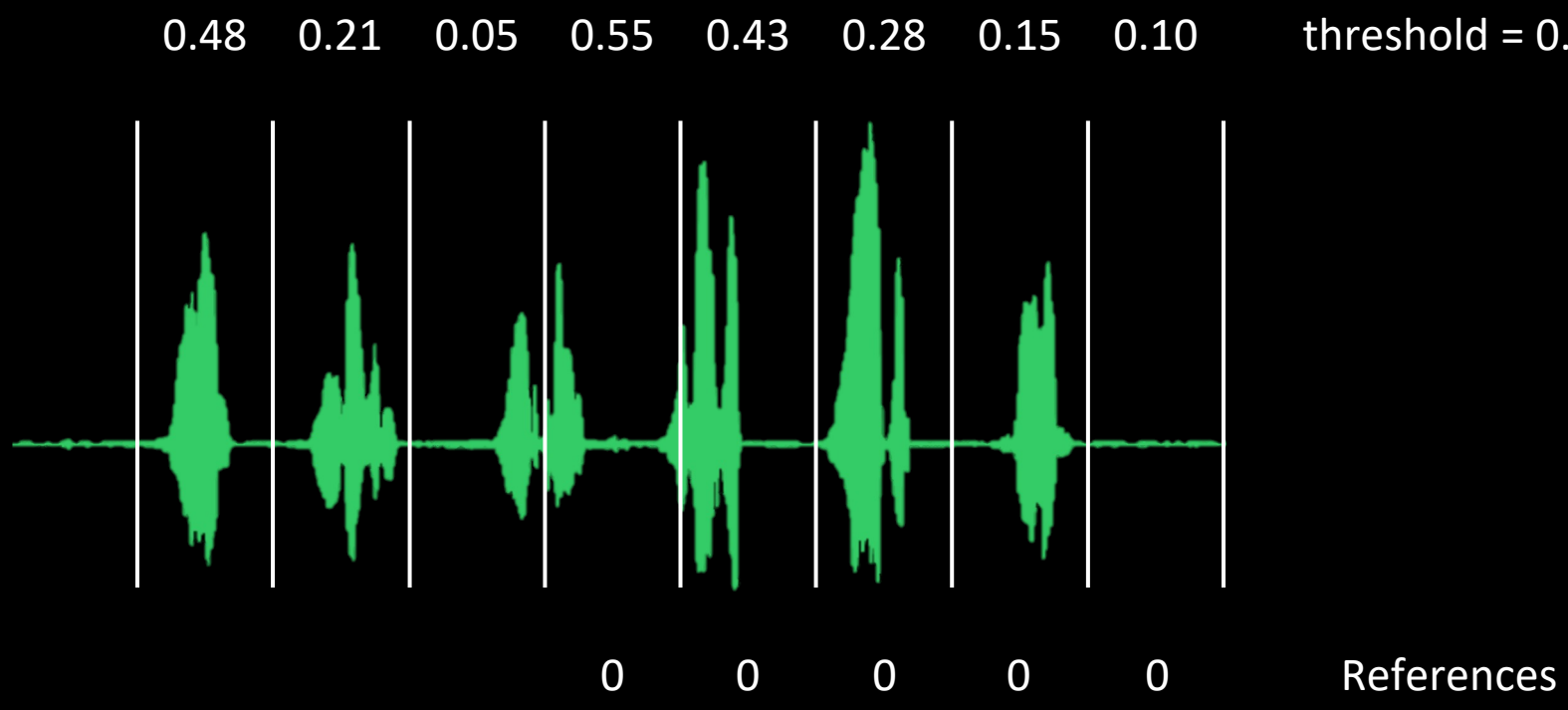
Endpoint detection



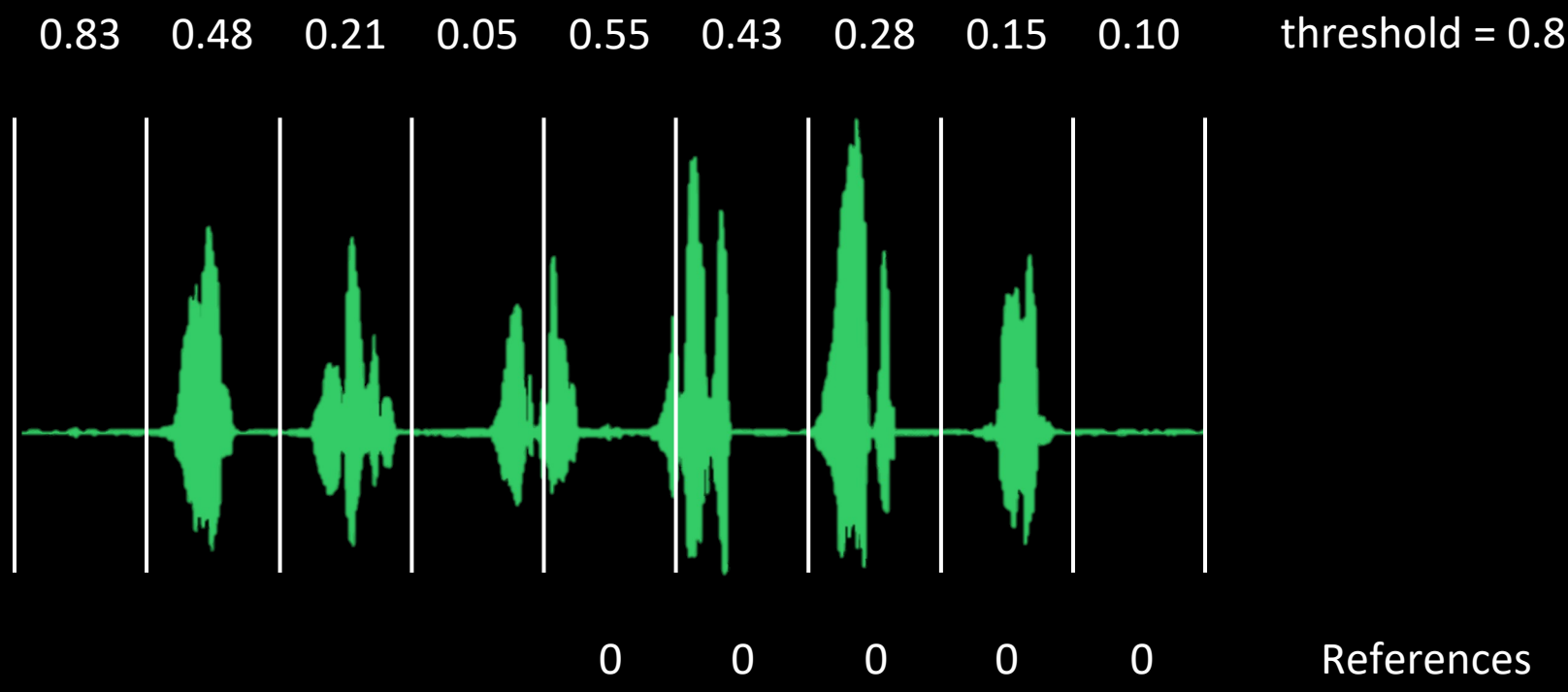
Endpoint detection



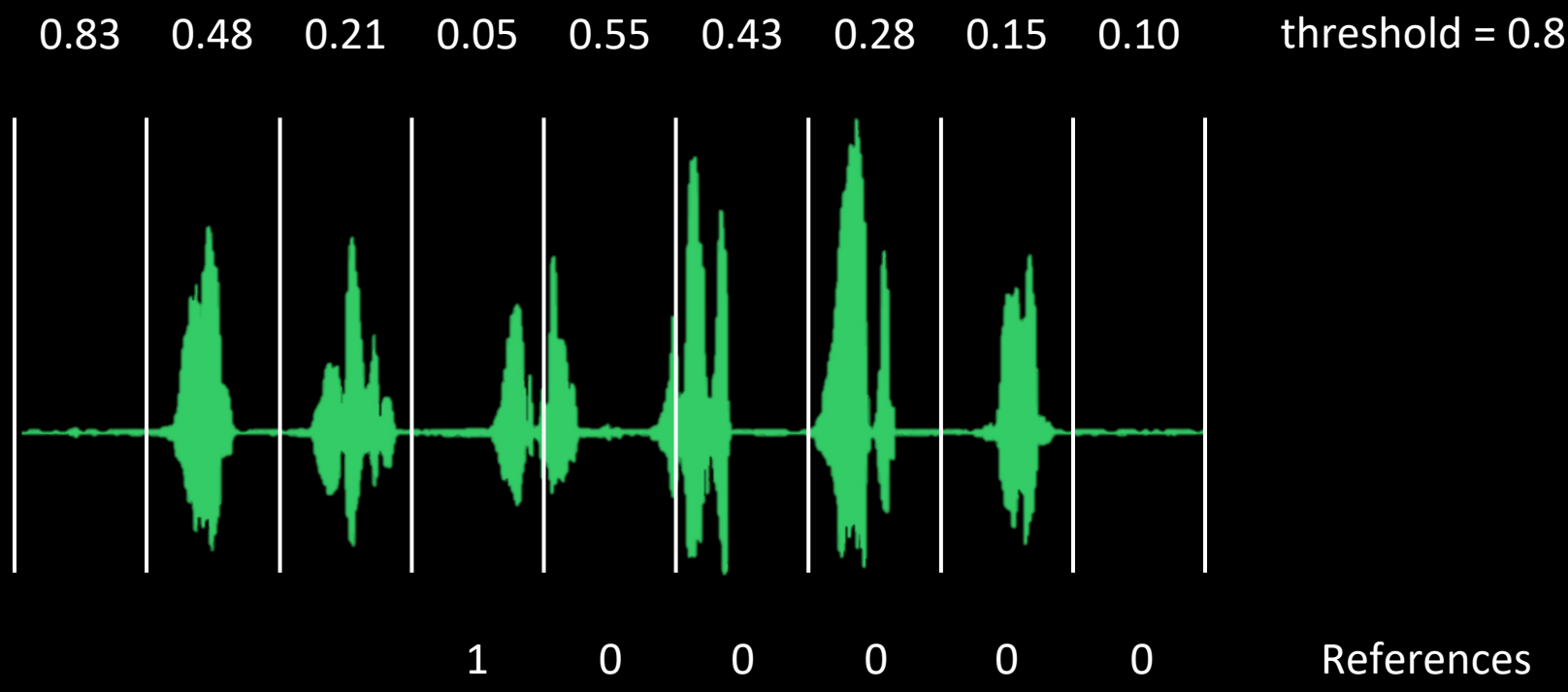
Endpoint detection



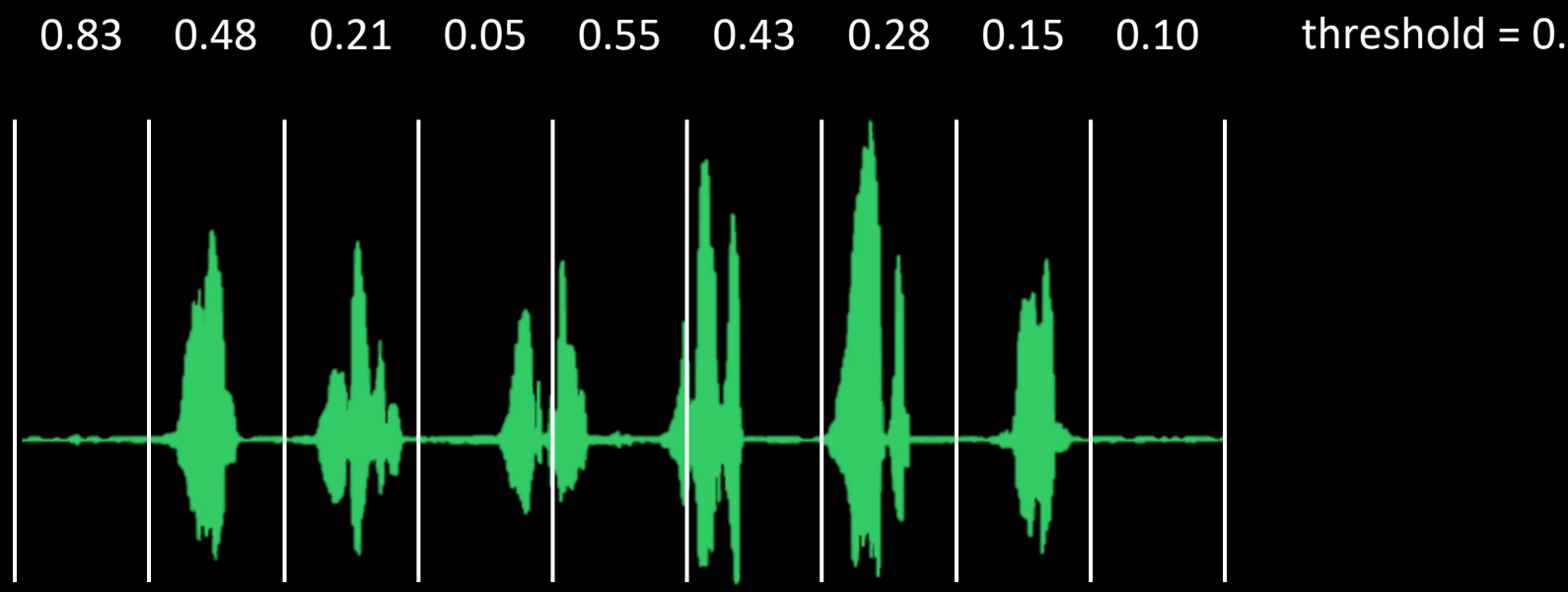
Endpoint detection



Endpoint detection



Endpoint detection



Late activation == latency 300ms

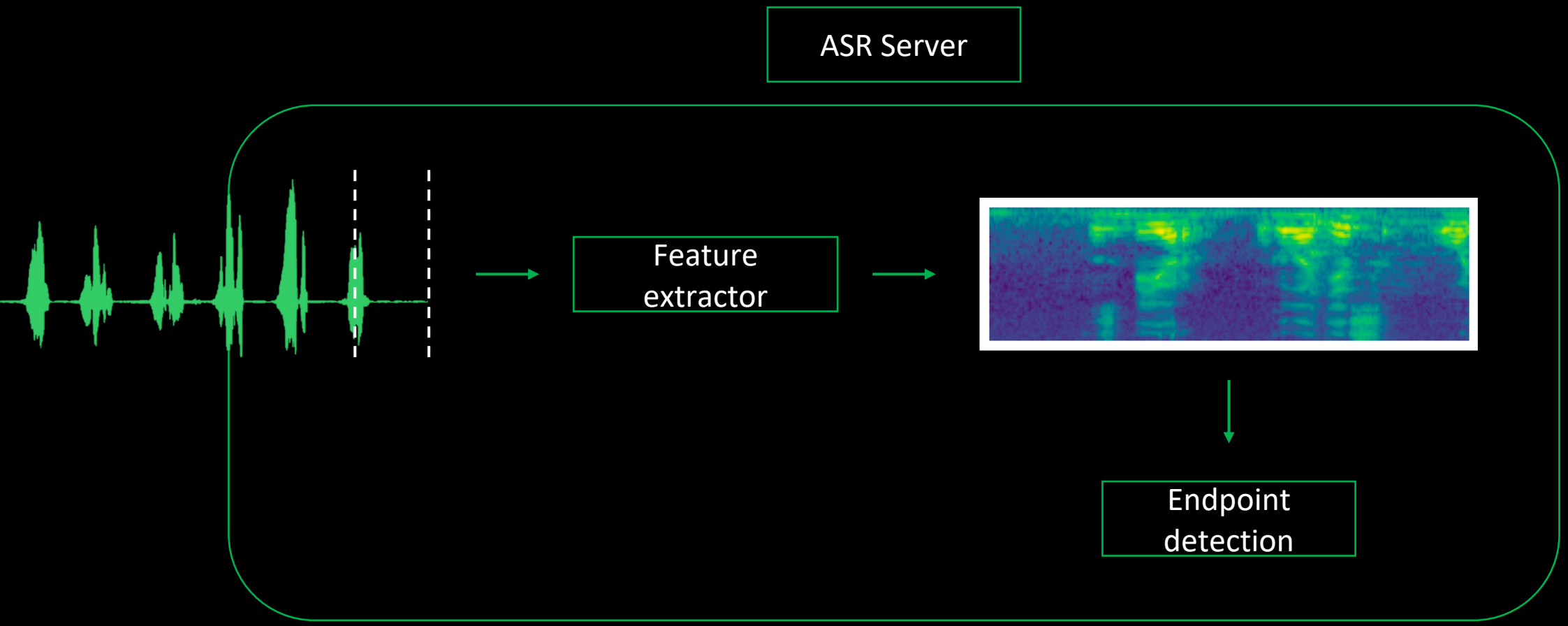
Endpoint detection: метрики

WERR: Word Error Rate Reduction
- WERR = $(WER_{old} - WER_{new}) / WER_{old} * 100\%$

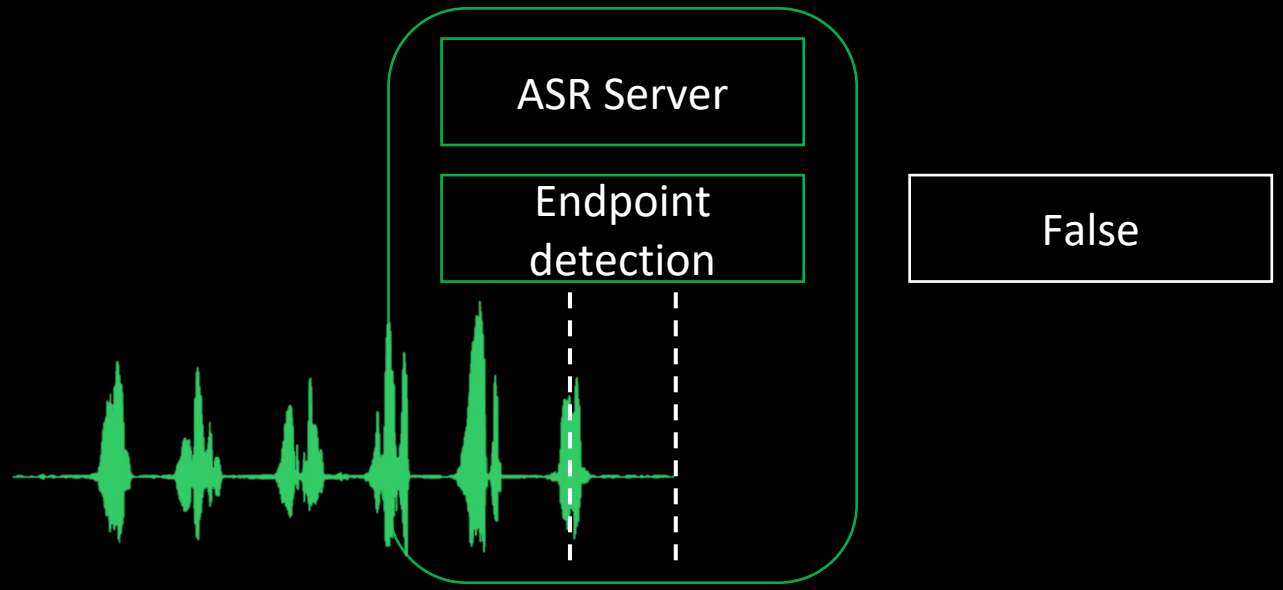
EEPR: Early Endpointing Rate
- Как часто предсказываем конец фразы до последнего слова в запросе

Latency
- Задержка между последним словом в запросе и предсказанием конца фразы
- Часто рассматривают различные квантили

Endpoint detection: audio features

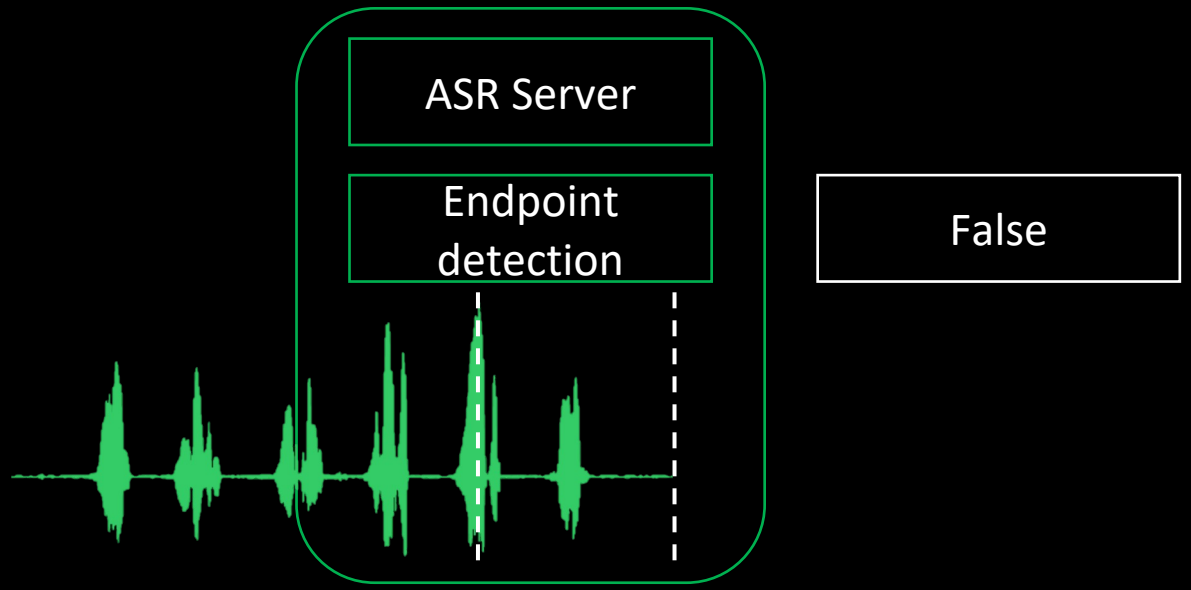


Endpoint detection: audio features



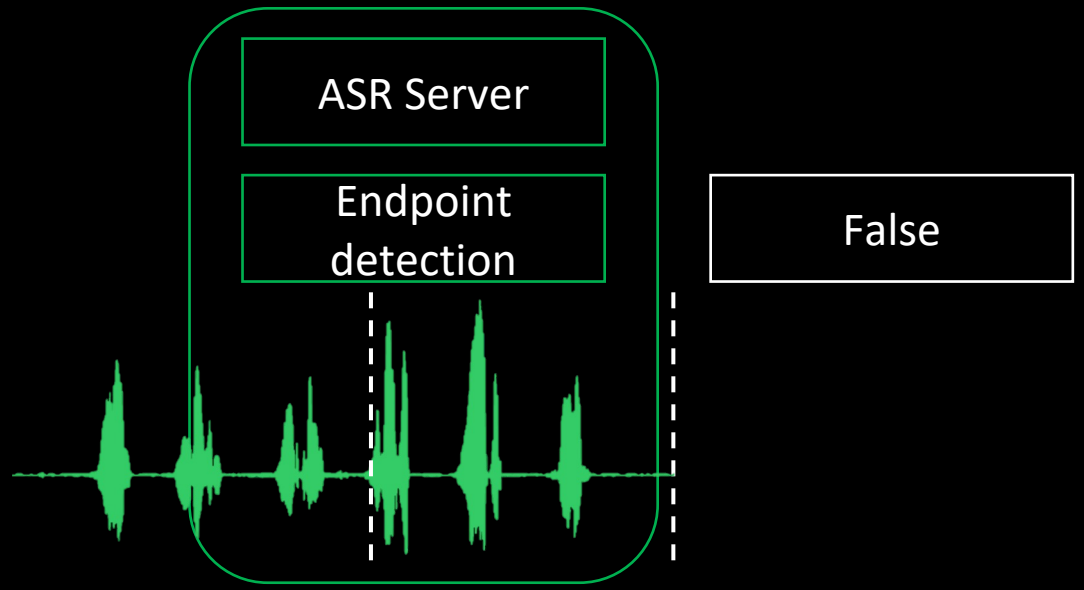
Assistant platform:
Intent recognition, Search,
Dialog Management, Skills

Endpoint detection: audio features



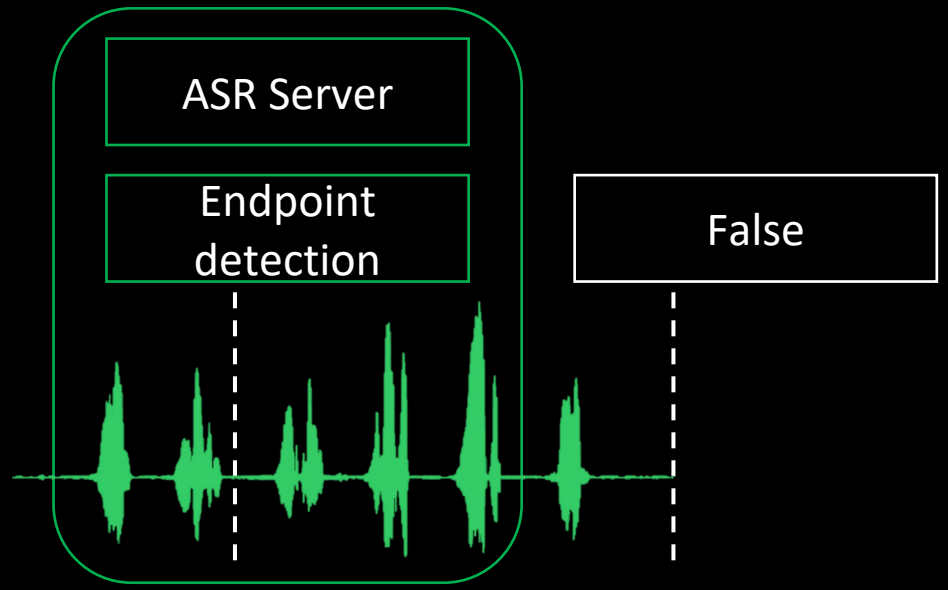
Assistant platform:
Intent recognition, Search,
Dialog Management, Skills

Endpoint detection: audio features



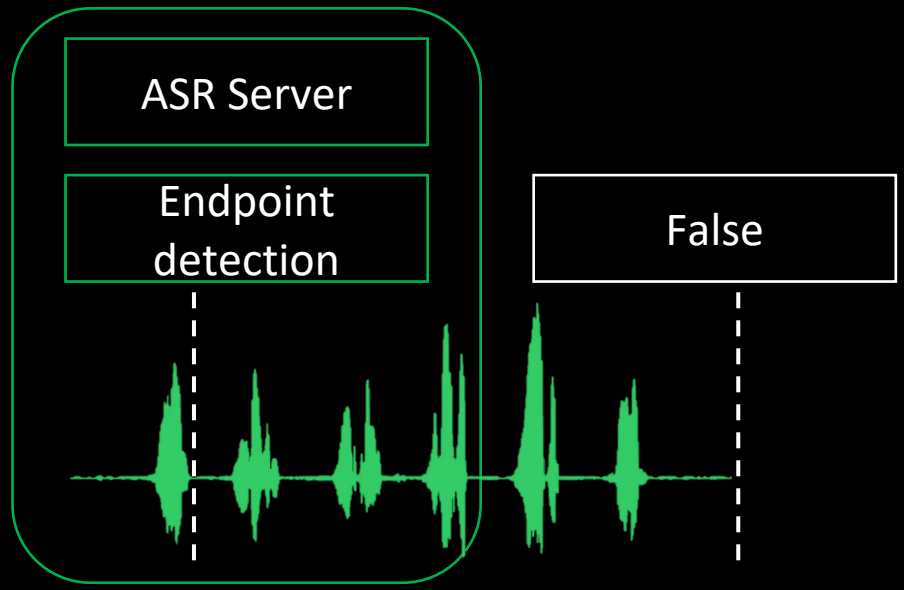
Assistant platform:
Intent recognition, Search,
Dialog Management, Skills

Endpoint detection: audio features



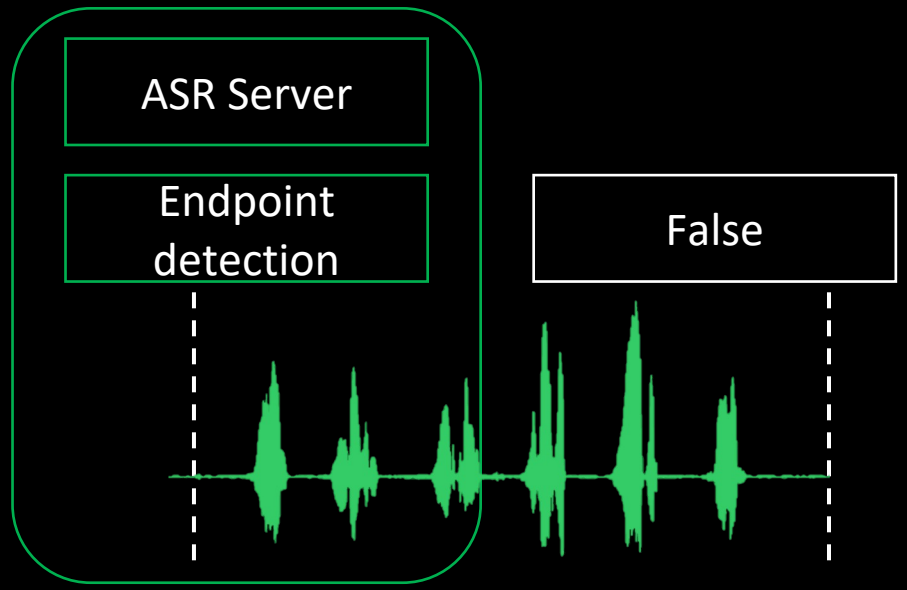
Assistant platform:
Intent recognition, Search,
Dialog Management, Skills

Endpoint detection: audio features



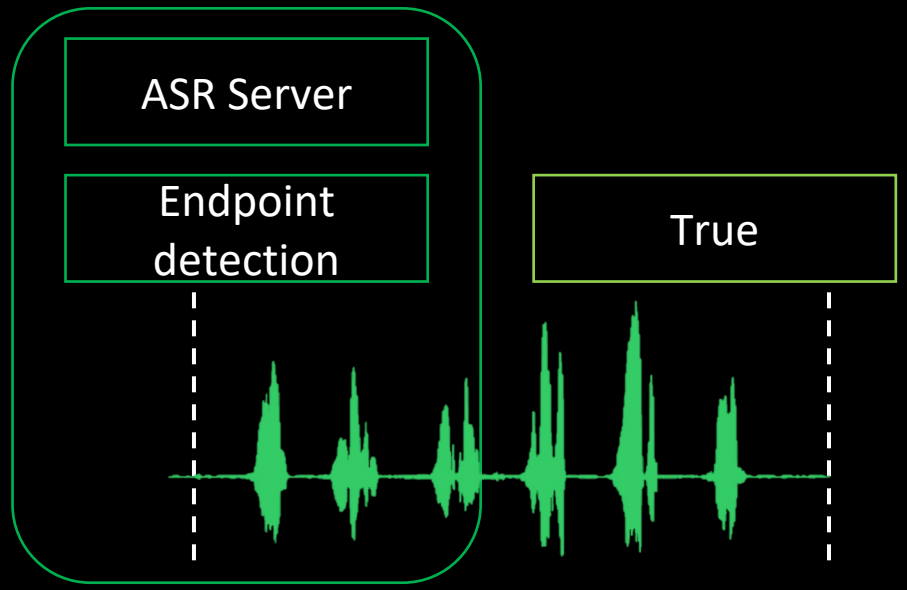
Assistant platform:
Intent recognition, Search,
Dialog Management, Skills

Endpoint detection: audio features



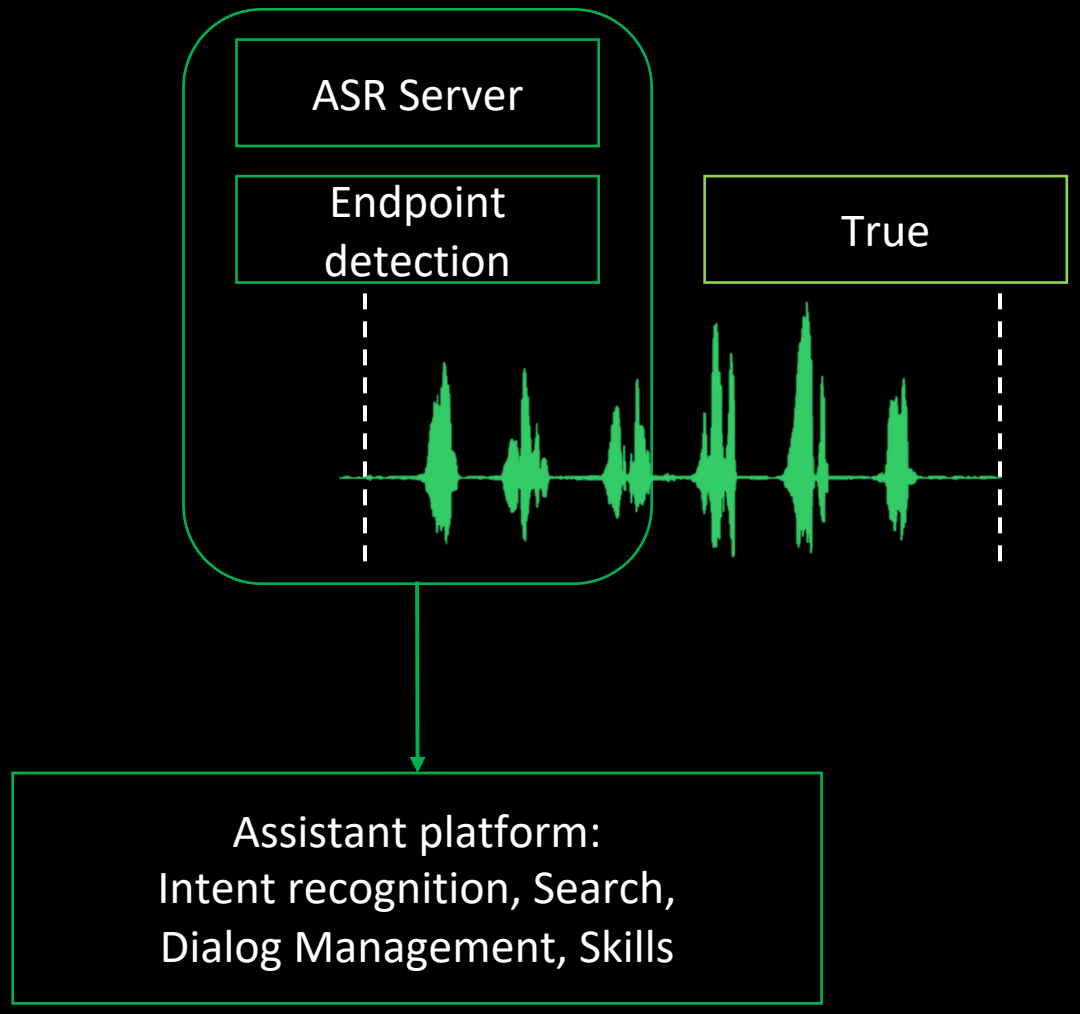
Assistant platform:
Intent recognition, Search,
Dialog Management, Skills

Endpoint detection: audio features



Assistant platform:
Intent recognition, Search,
Dialog Management, Skills

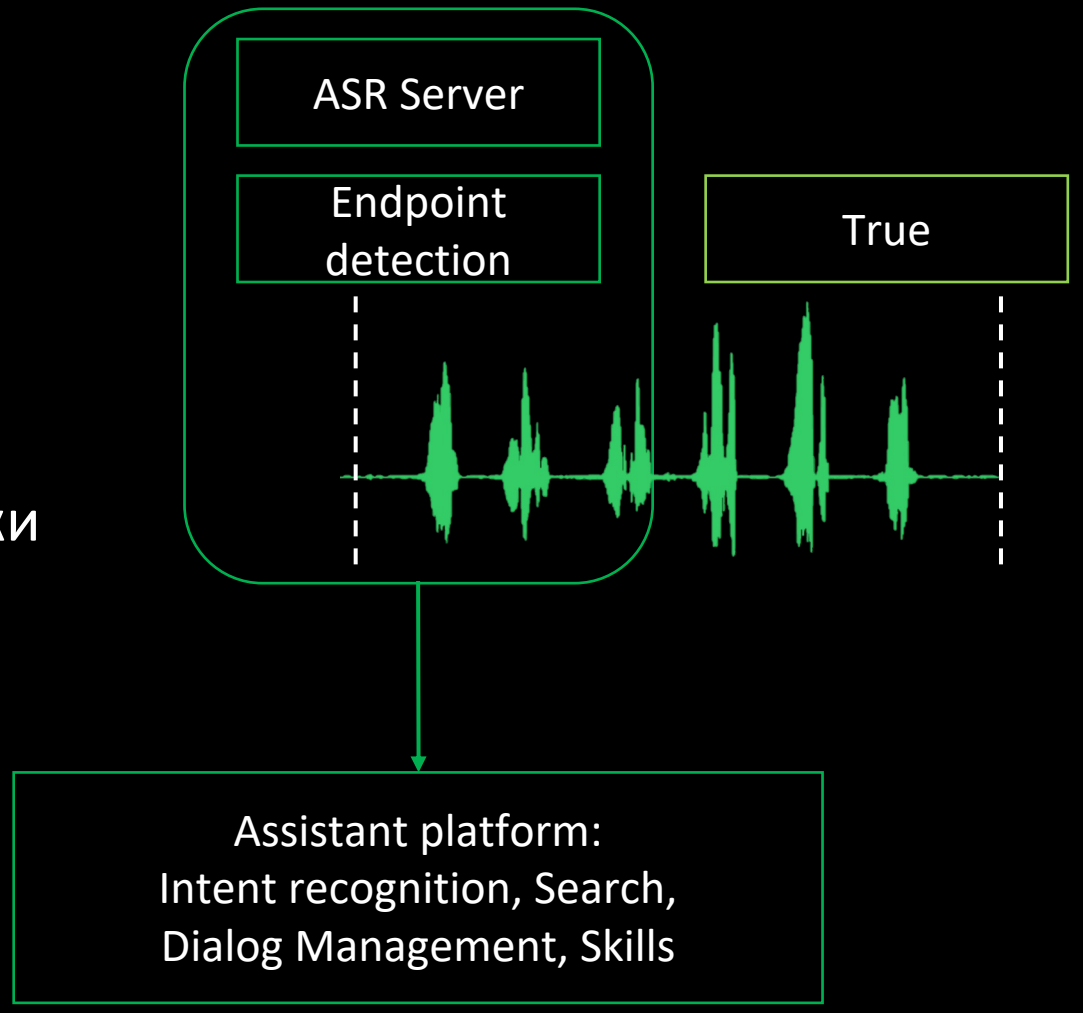
Endpoint detection: audio features



Endpoint detection: audio features

Преимущества:
- Скорость инференса
- Простота системы

Недостатки:
- Точность
- Не учитываем текстовые признаки

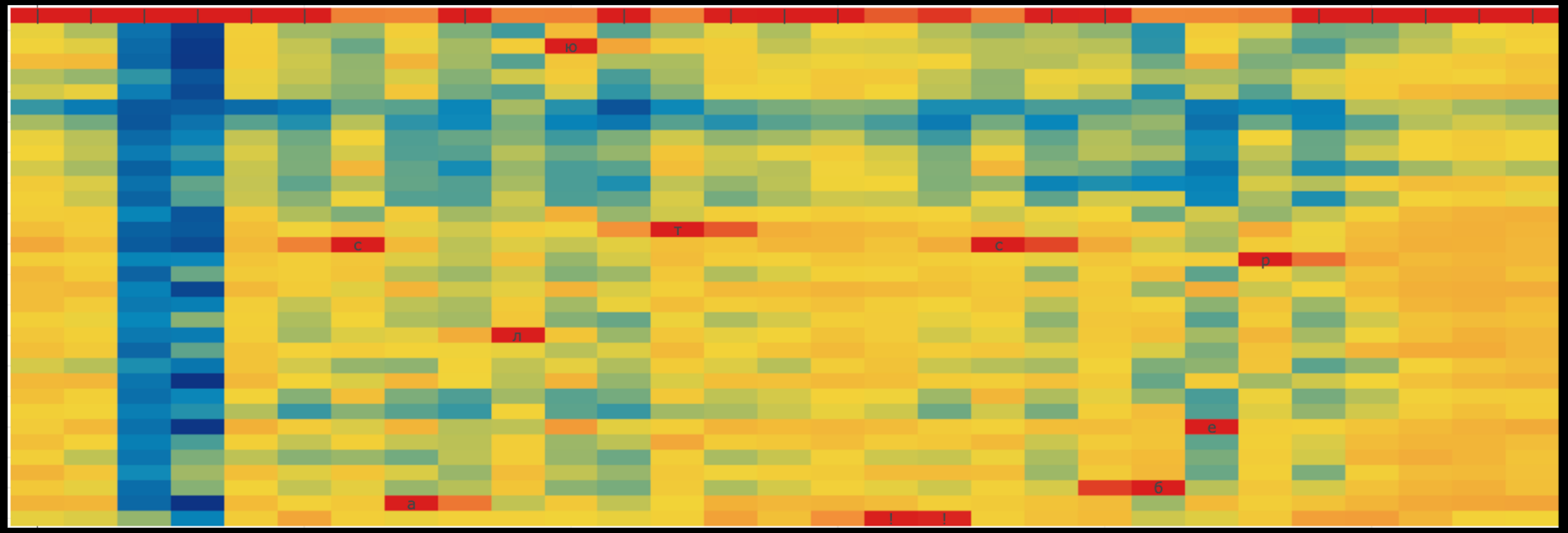


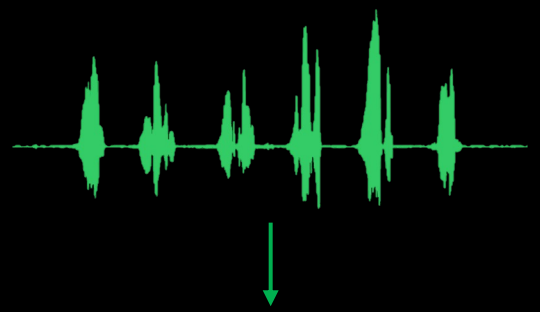
Endpoint detection: audio features

Что еще?

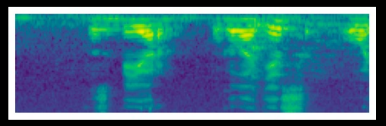
Endpoint detection: audio features

Предсказание конца запроса по логитам CTC





Feature Extractor

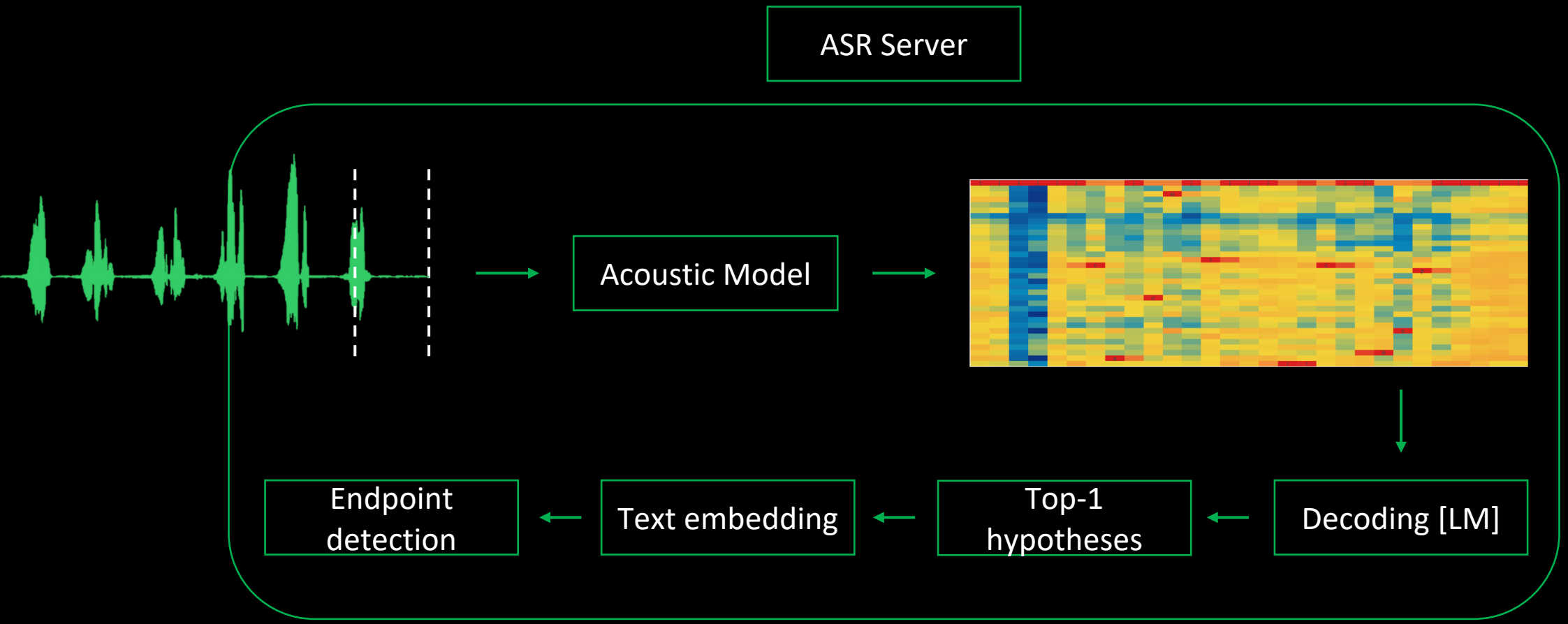


Char-CTC Acoustic Model

Endpoint detection: text features

Предсказание конца запроса на основе text features
- Оценка завершенности запроса по гипотезам ASR

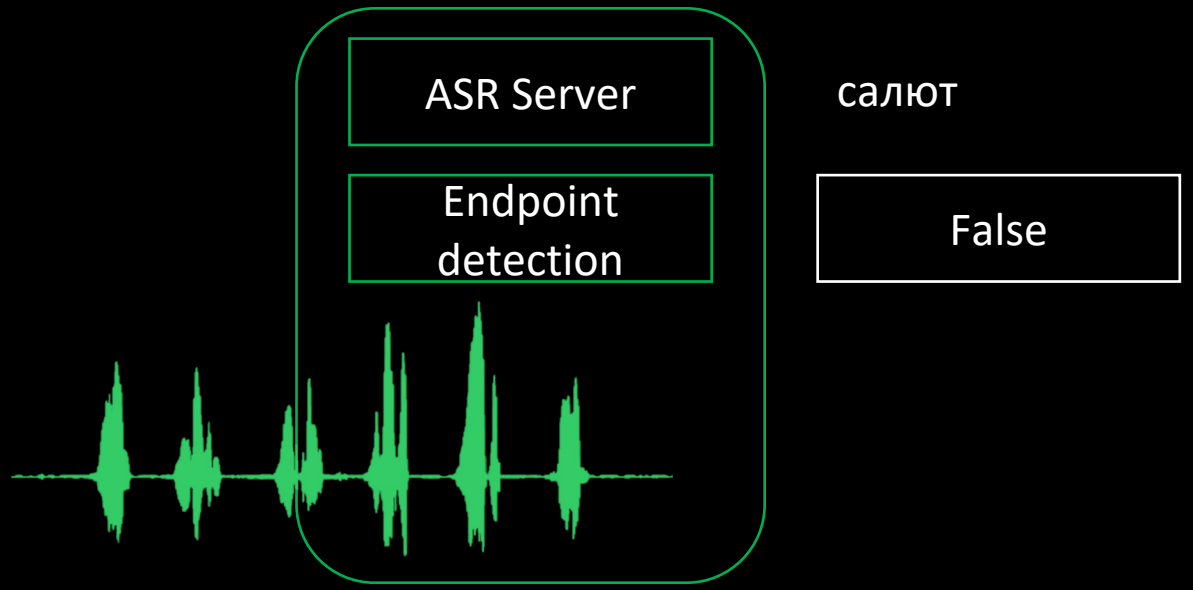
Endpoint detection: text features



Endpoint detection: text features

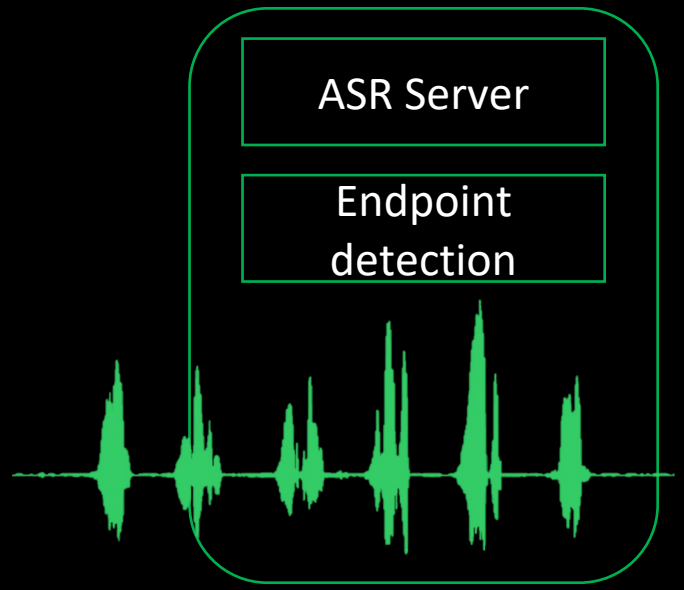
Assistant platform:
Intent recognition, Search,
Dialog Management, Skills

Endpoint detection: text features



Assistant platform:
Intent recognition, Search,
Dialog Management, Skills

Endpoint detection: text features

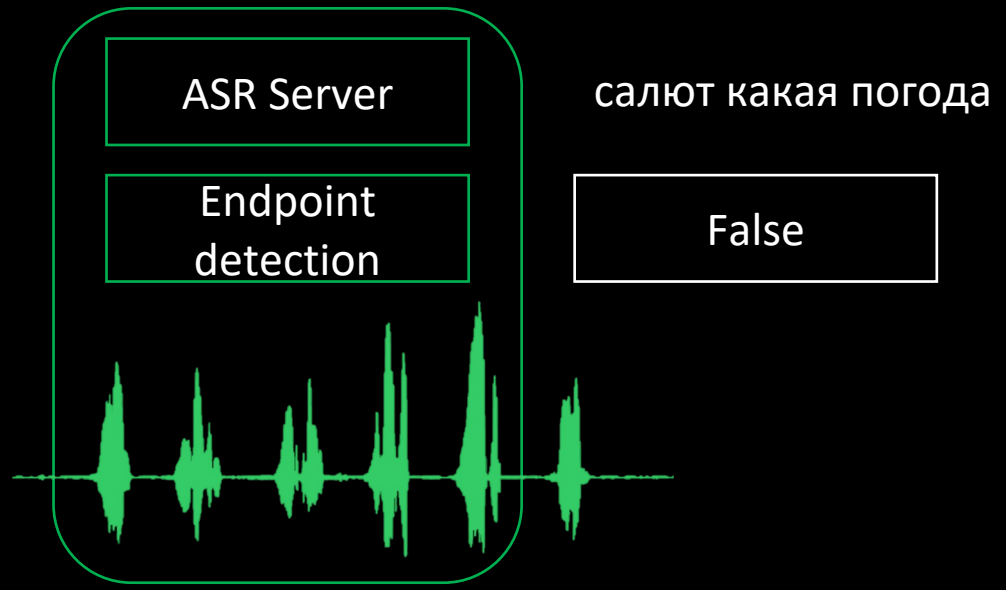


салют какая

False

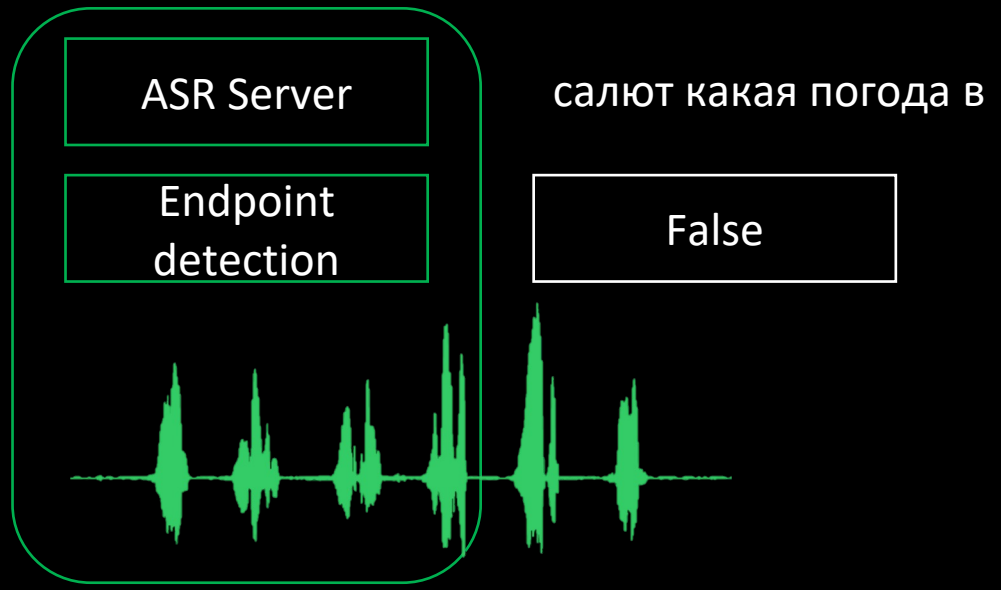
Assistant platform:
Intent recognition, Search,
Dialog Management, Skills

Endpoint detection: text features



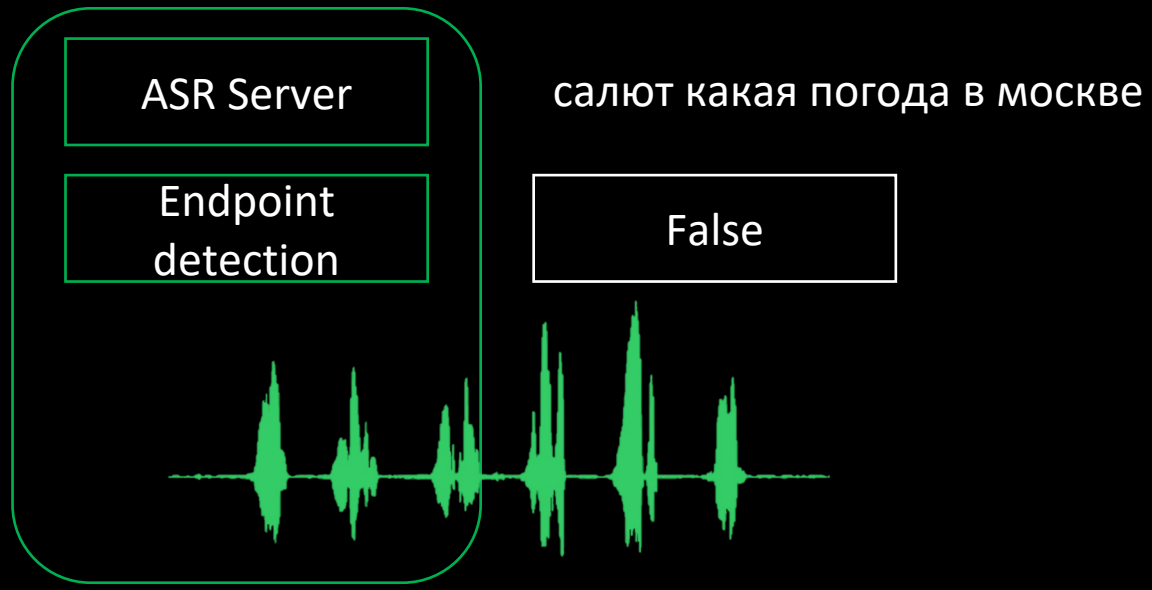
Assistant platform:
Intent recognition, Search,
Dialog Management, Skills

Endpoint detection: text features



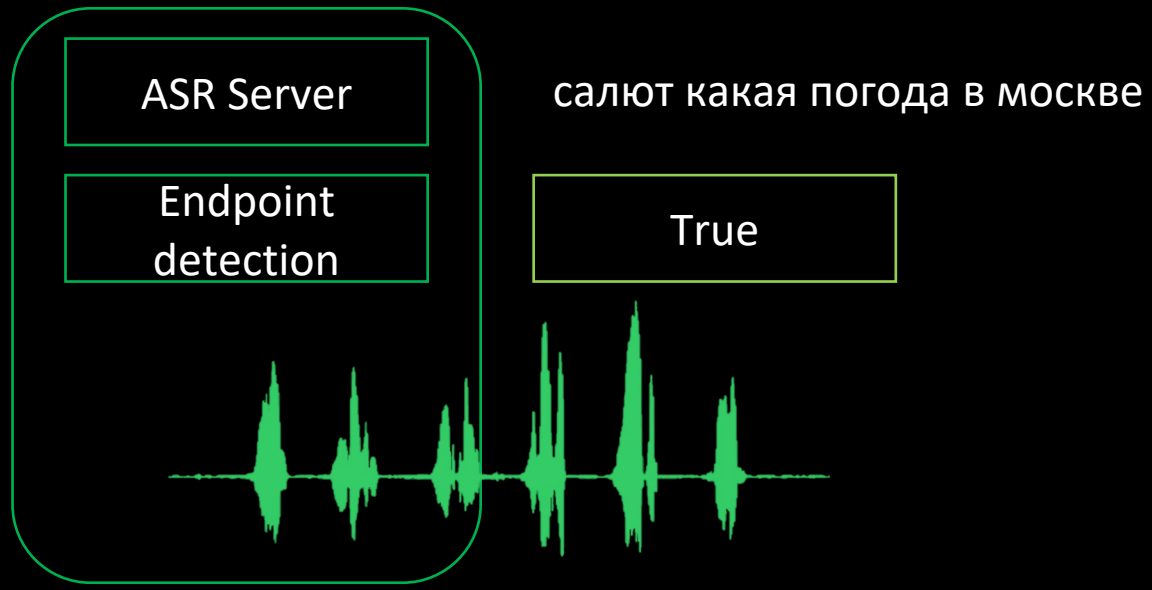
Assistant platform:
Intent recognition, Search,
Dialog Management, Skills

Endpoint detection: text features



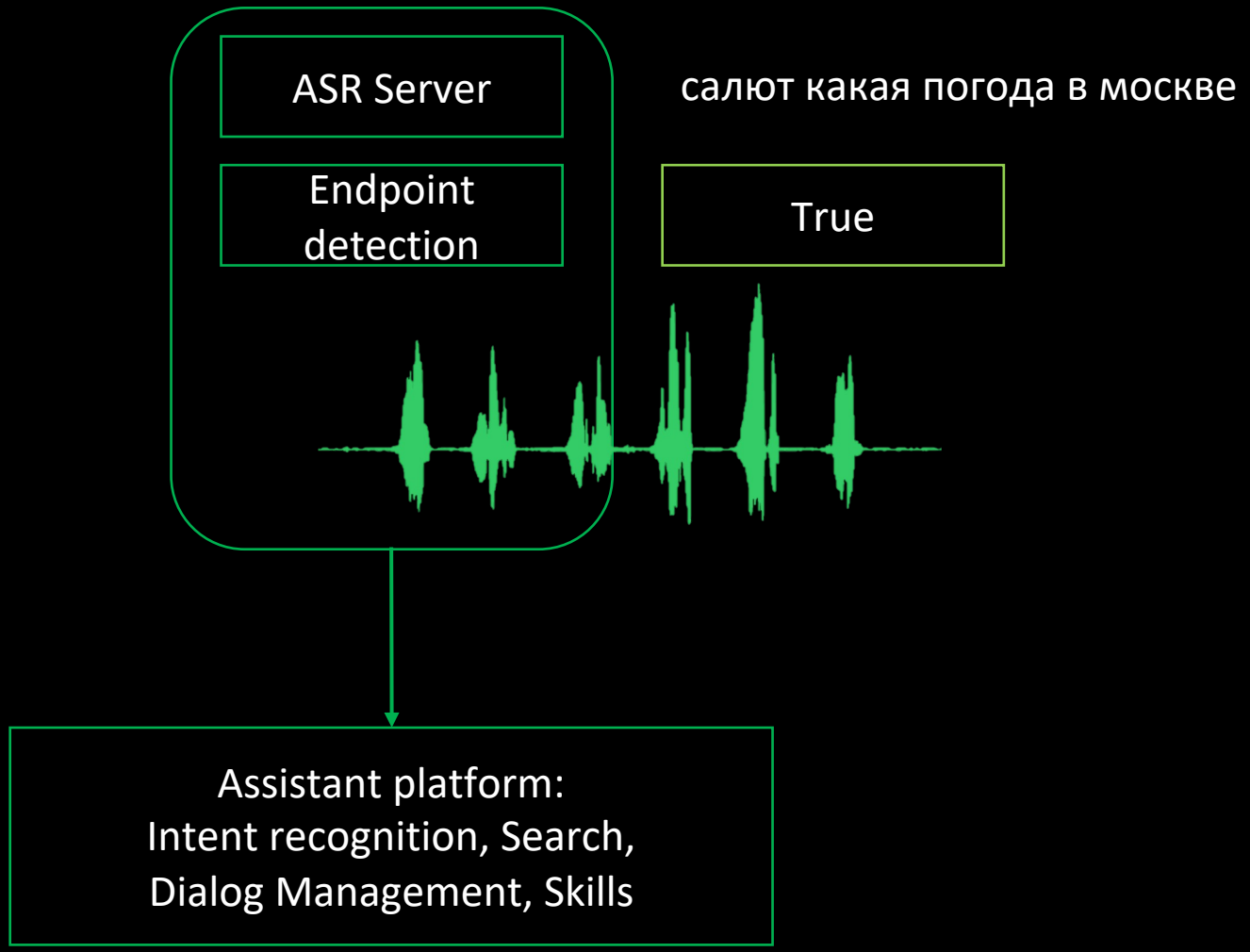
Assistant platform:
Intent recognition, Search,
Dialog Management, Skills

Endpoint detection: text features



Assistant platform:
Intent recognition, Search,
Dialog Management, Skills

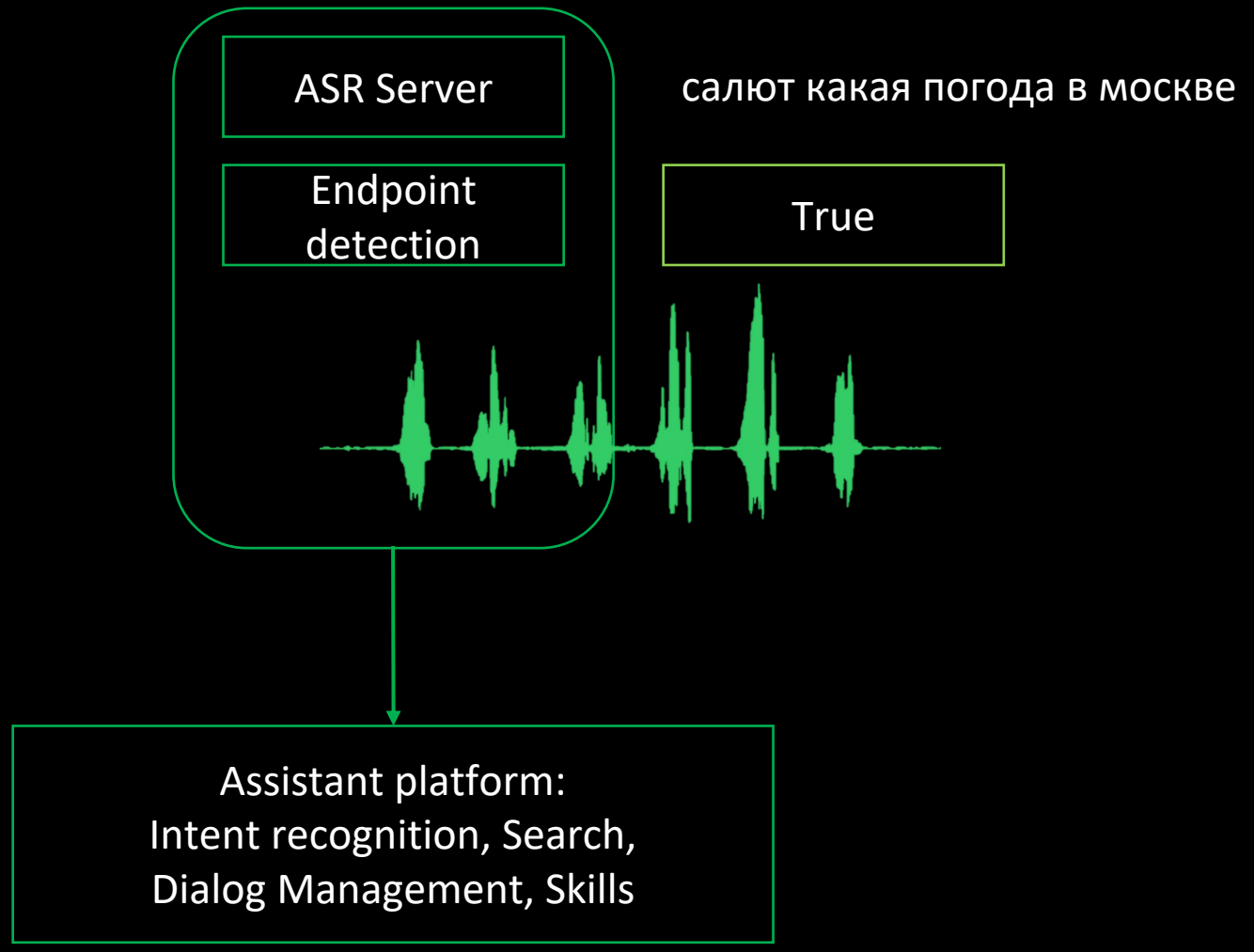
Endpoint detection: text features



Endpoint detection: text features

Преимущества:
- Скорость инференса
- Простота системы

Недостатки:
- Точность
- Не учитываем аудио признаки
- Ошибки ASR модели



Endpoint detection: multimodal system

Предсказание конца запроса на основе audio & text features

Endpoint detection: multimodal system

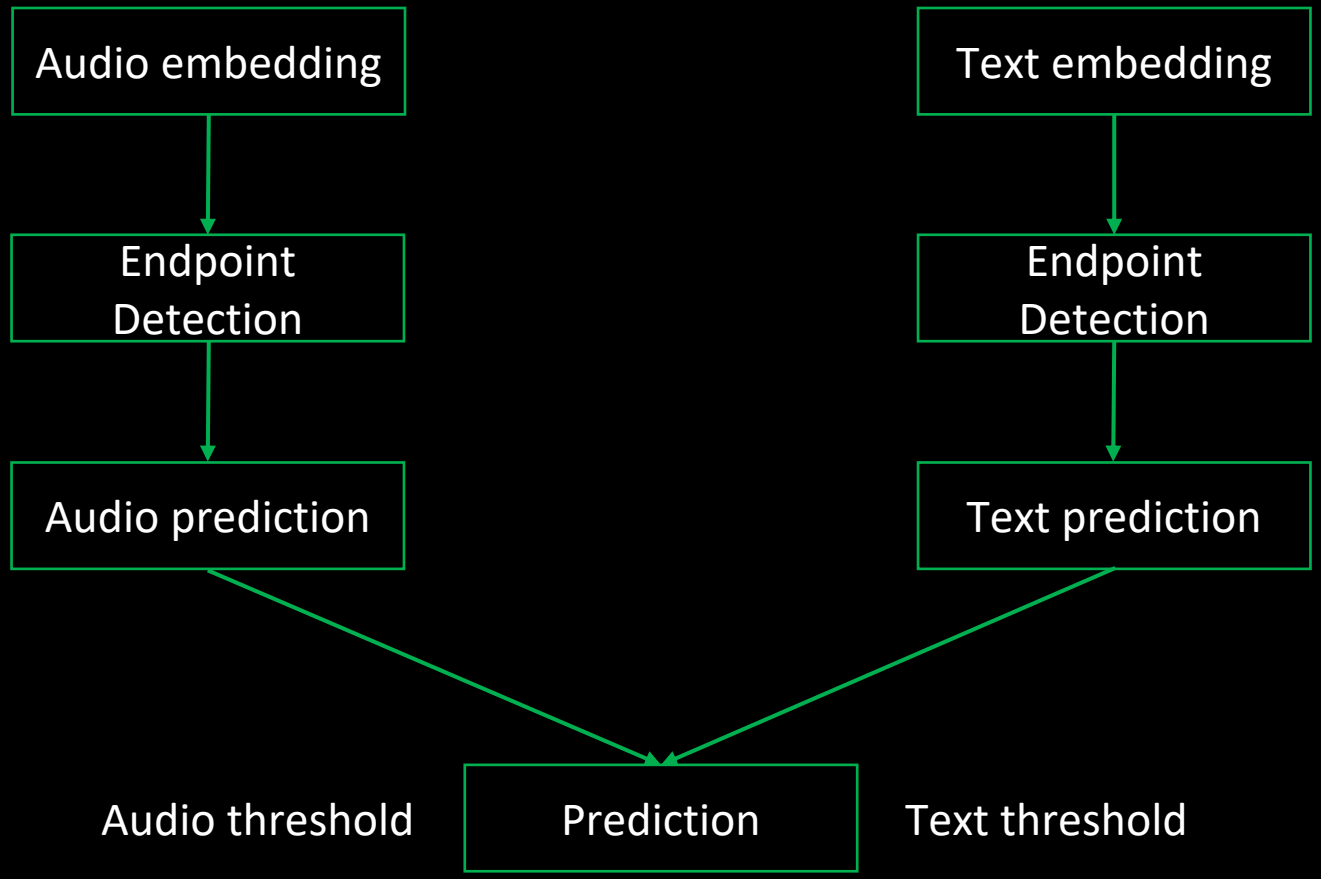
Предсказание конца запроса на основе audio & text features
Как можно объединить audio & text features?

Endpoint detection: multimodal system

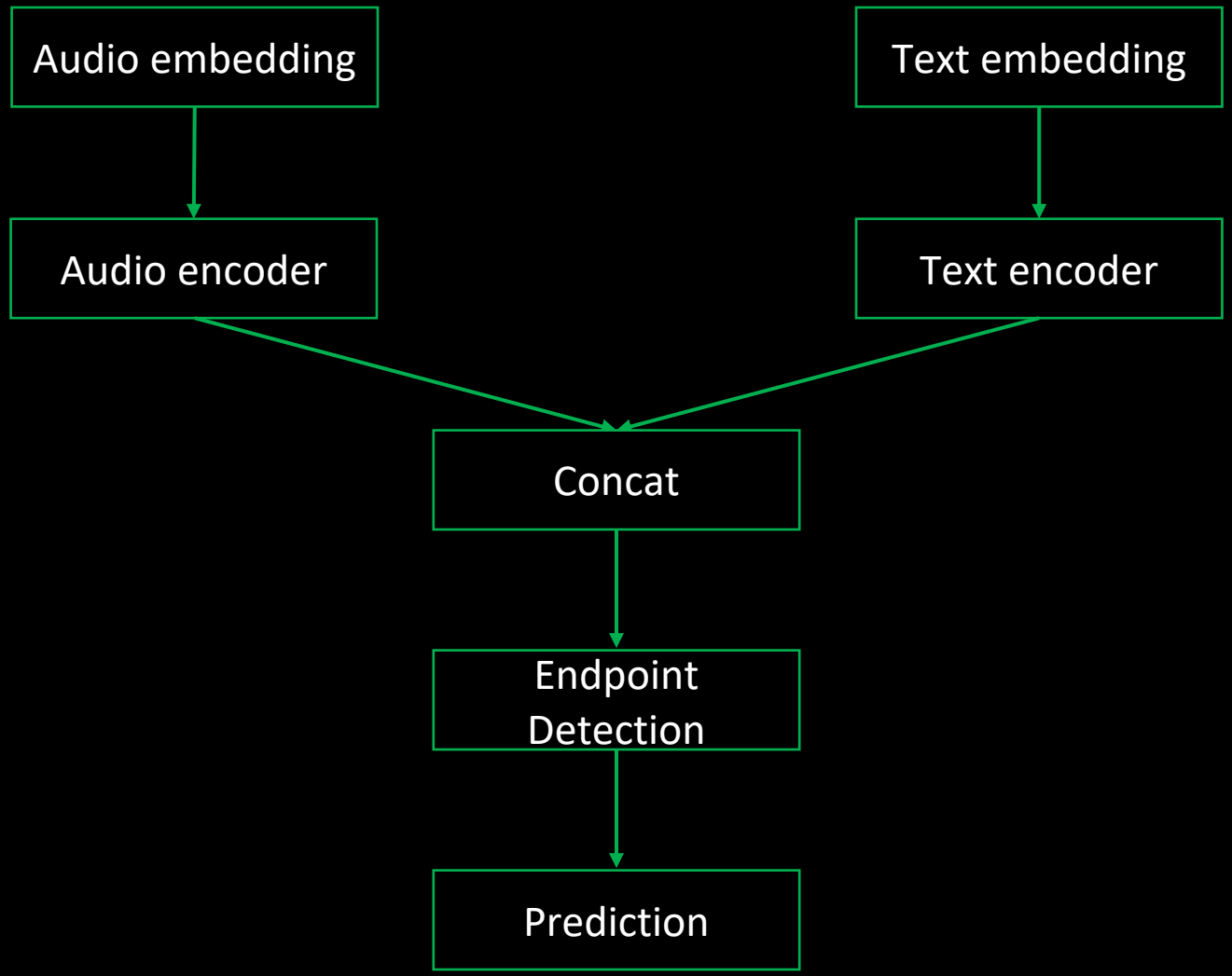
Audio embedding

Text embedding

Endpoint detection: multimodal system



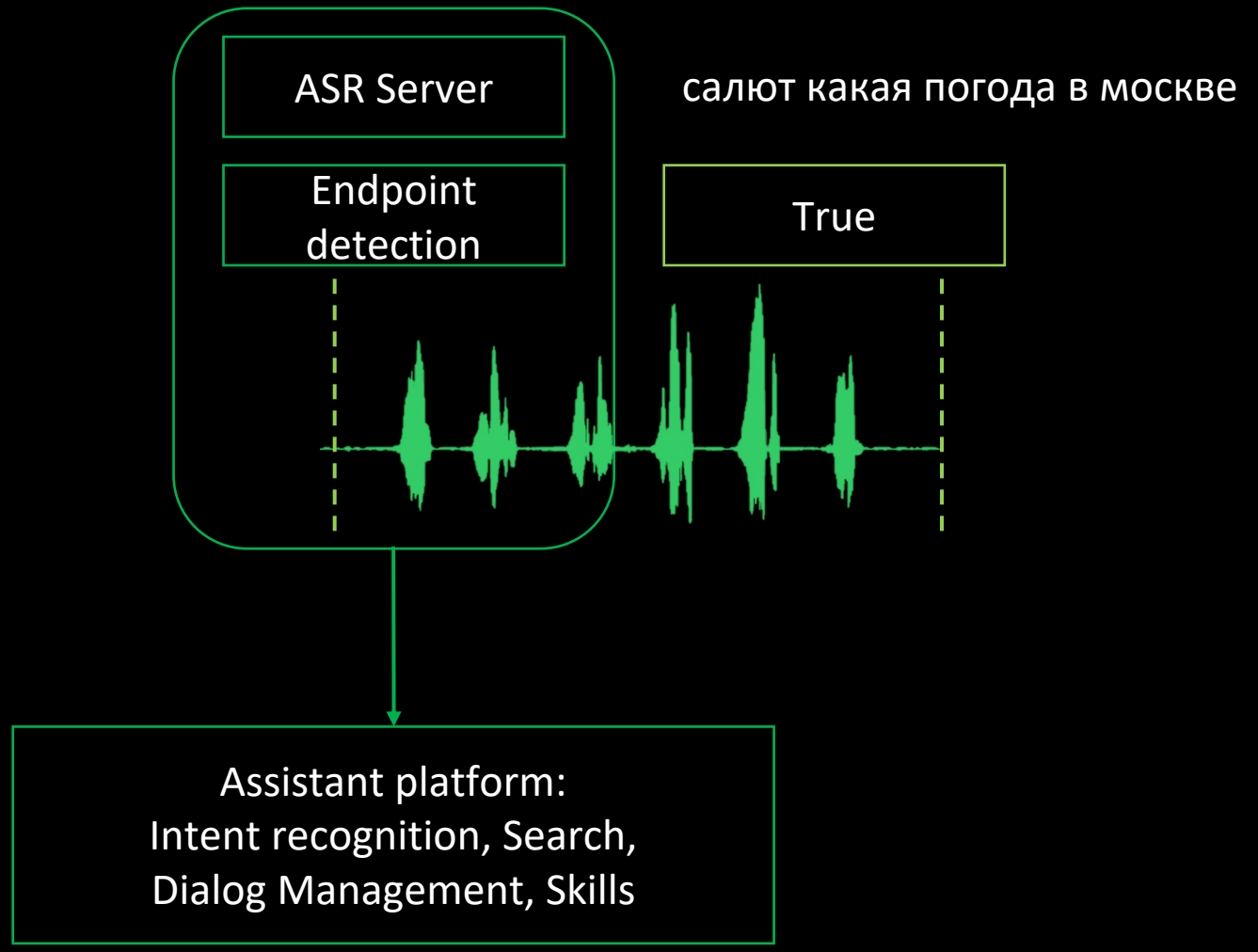
Endpoint detection: multimodal system



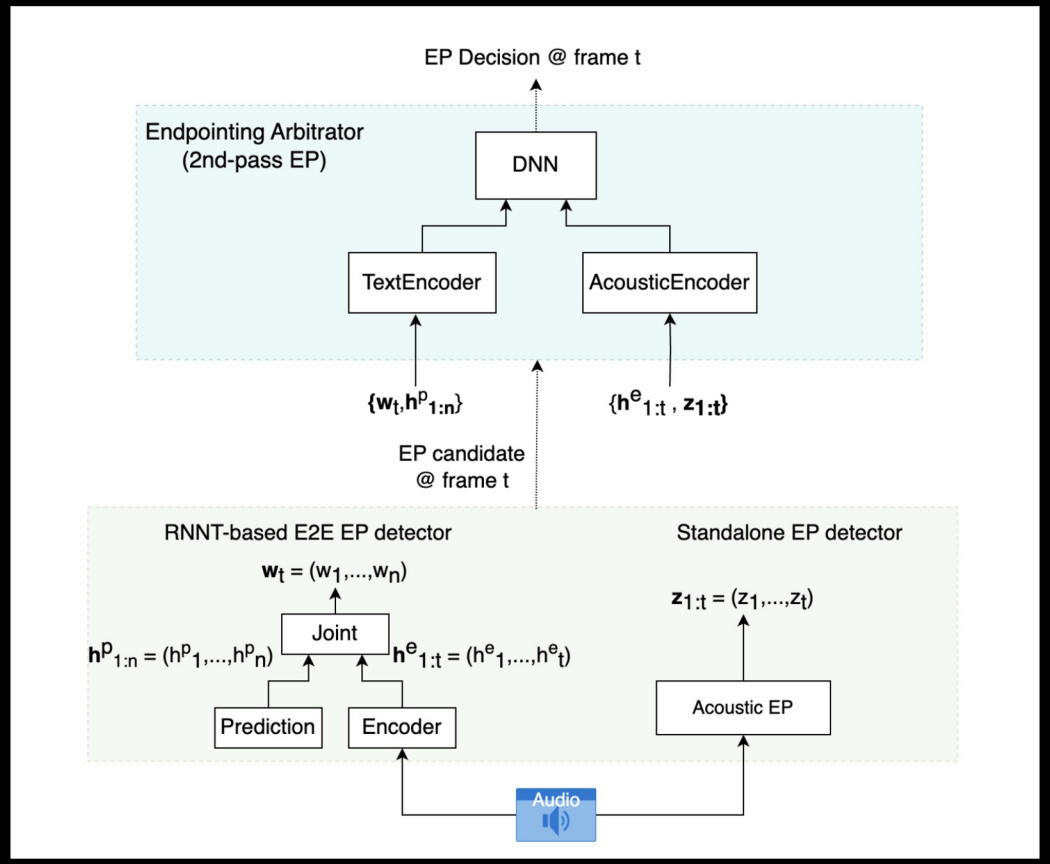
Endpoint detection: multimodal system

Преимущества:
- Точность
- Учет audio & text признаков

Недостатки:
- Сложность системы



Endpoint detection: multimodal system



Two-pass endpoint detection for speech recognition: Amazon Alexa AI, 2024

User perceived latency

Скорость отклика
- Быстрое выполнение команд, без задержек и пауз

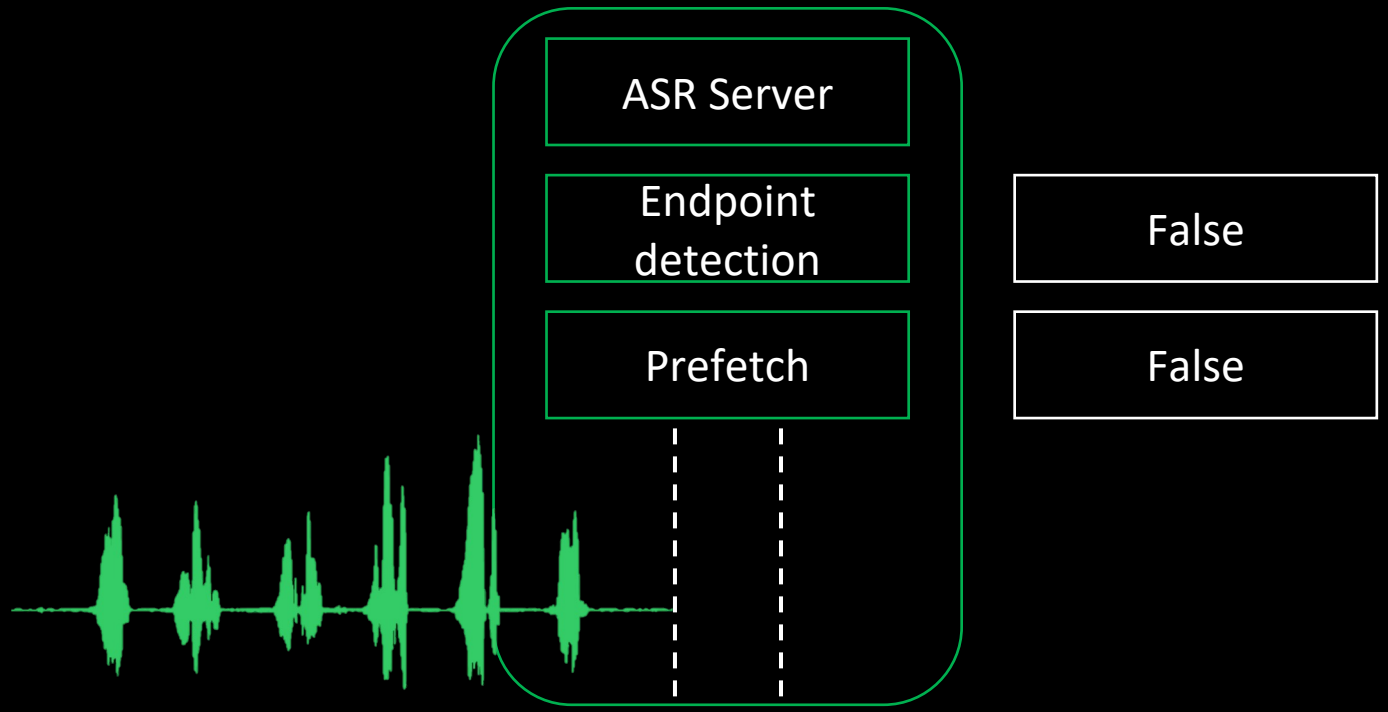
User perceived latency – метрика, отражающая воспринимаемое пользователем время задержки между действием и реакцией системы.

В нашем случае можем выделить два примера:
- Произношение активационной фразы <-> активация колонки
- Произношение голосового запроса <-> получение ответа

User perceived latency: prefetch recognition

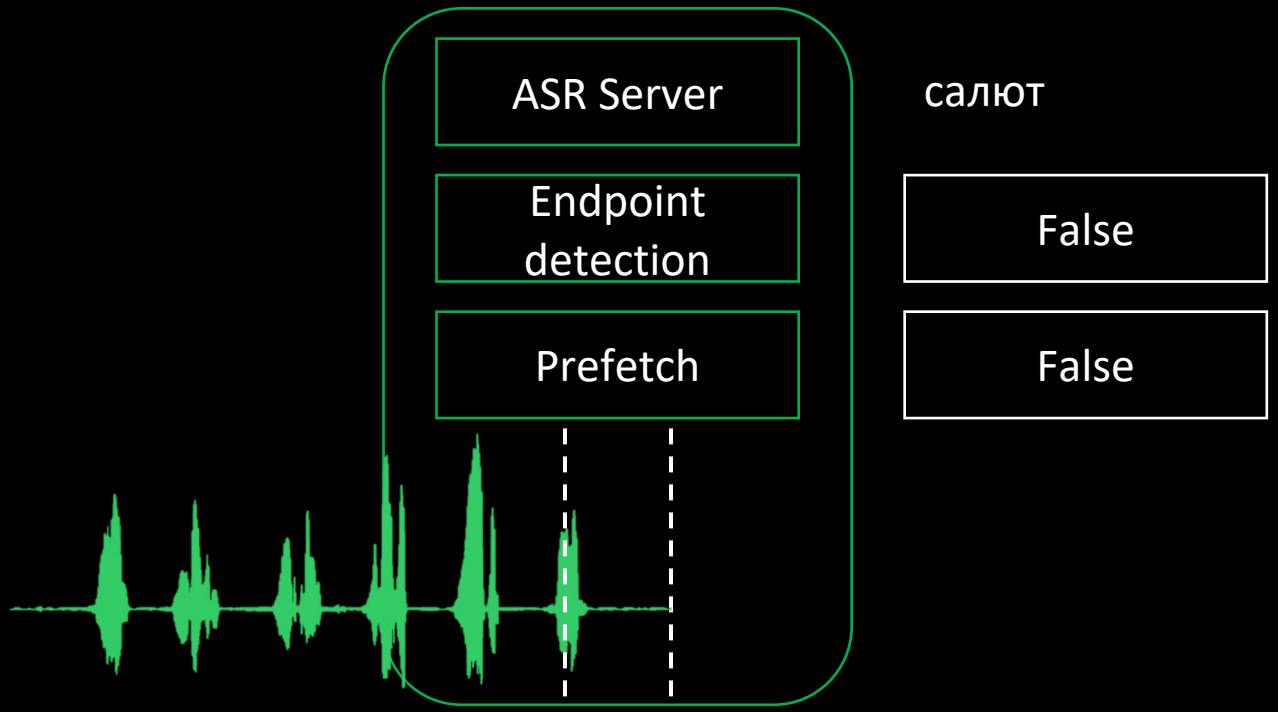
Основная задача в рамках Voice Assistant Pipeline
- Оценка завершенности частично распознанного запроса

User perceived latency: prefetch recognition



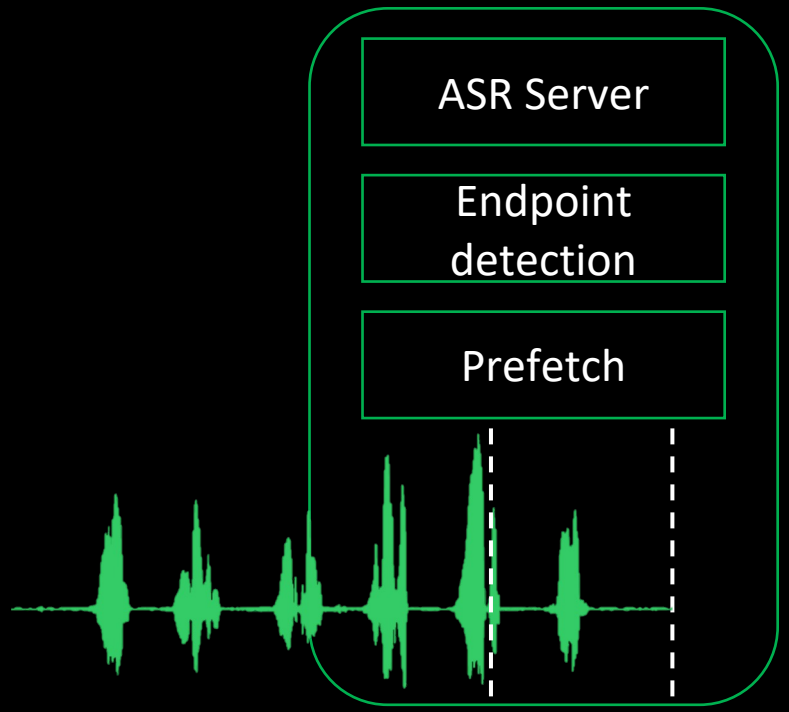
Assistant platform:
Intent recognition, Search,
Dialog Management, Skills

User perceived latency: prefetch recognition



Assistant platform:
Intent recognition, Search,
Dialog Management, Skills

User perceived latency: prefetch recognition

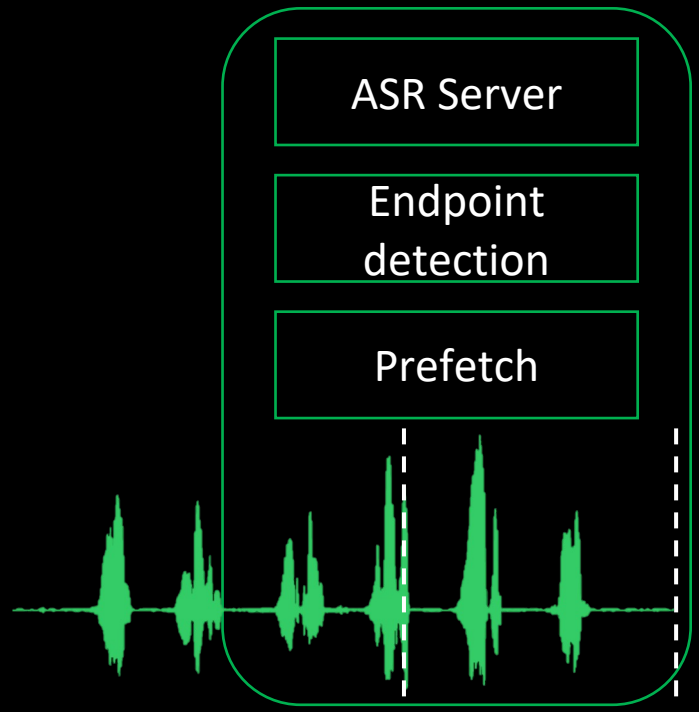


салют какая

False
False

Assistant platform:
Intent recognition, Search,
Dialog Management, Skills

User perceived latency: prefetch recognition



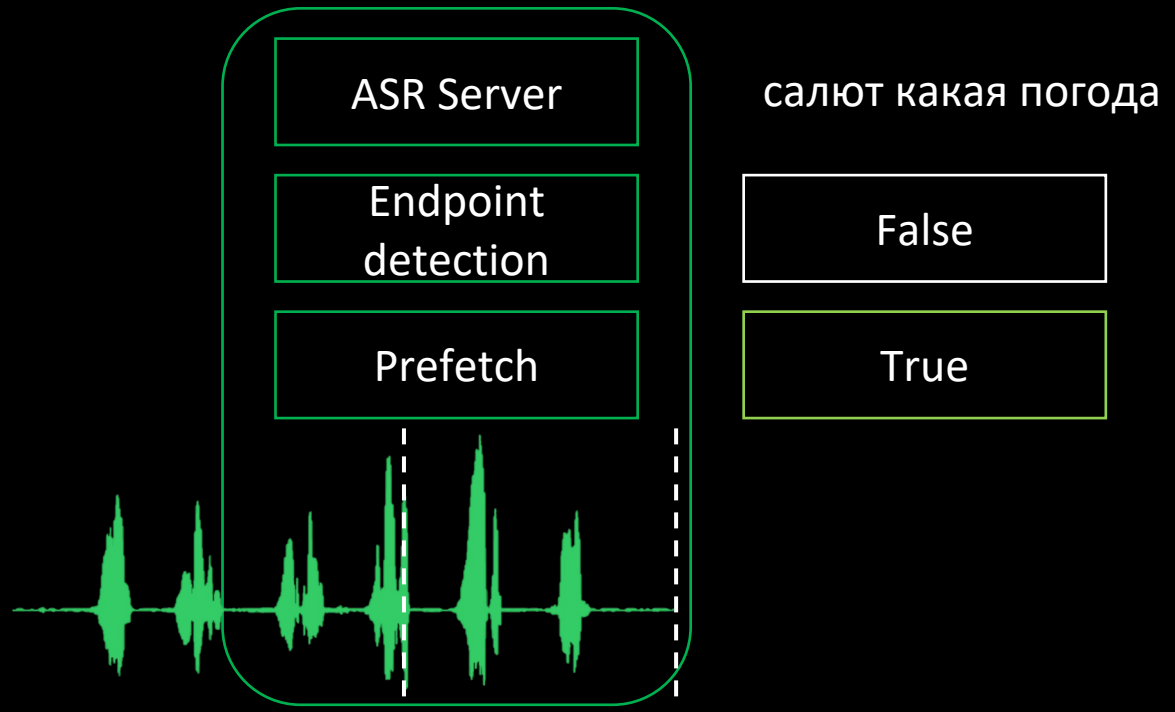
салют какая погода

False

False

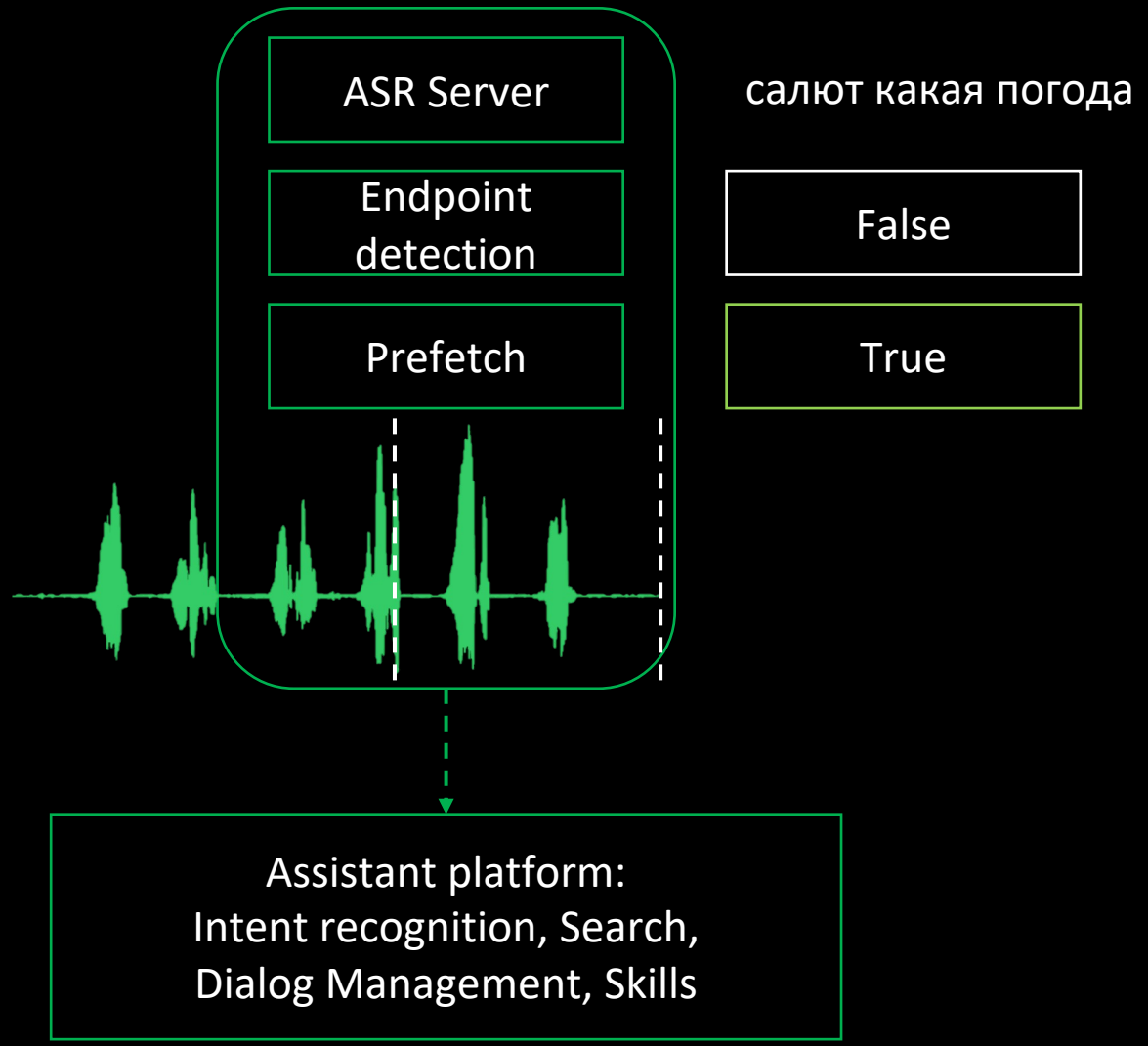
Assistant platform:
Intent recognition, Search,
Dialog Management, Skills

User perceived latency: prefetch recognition

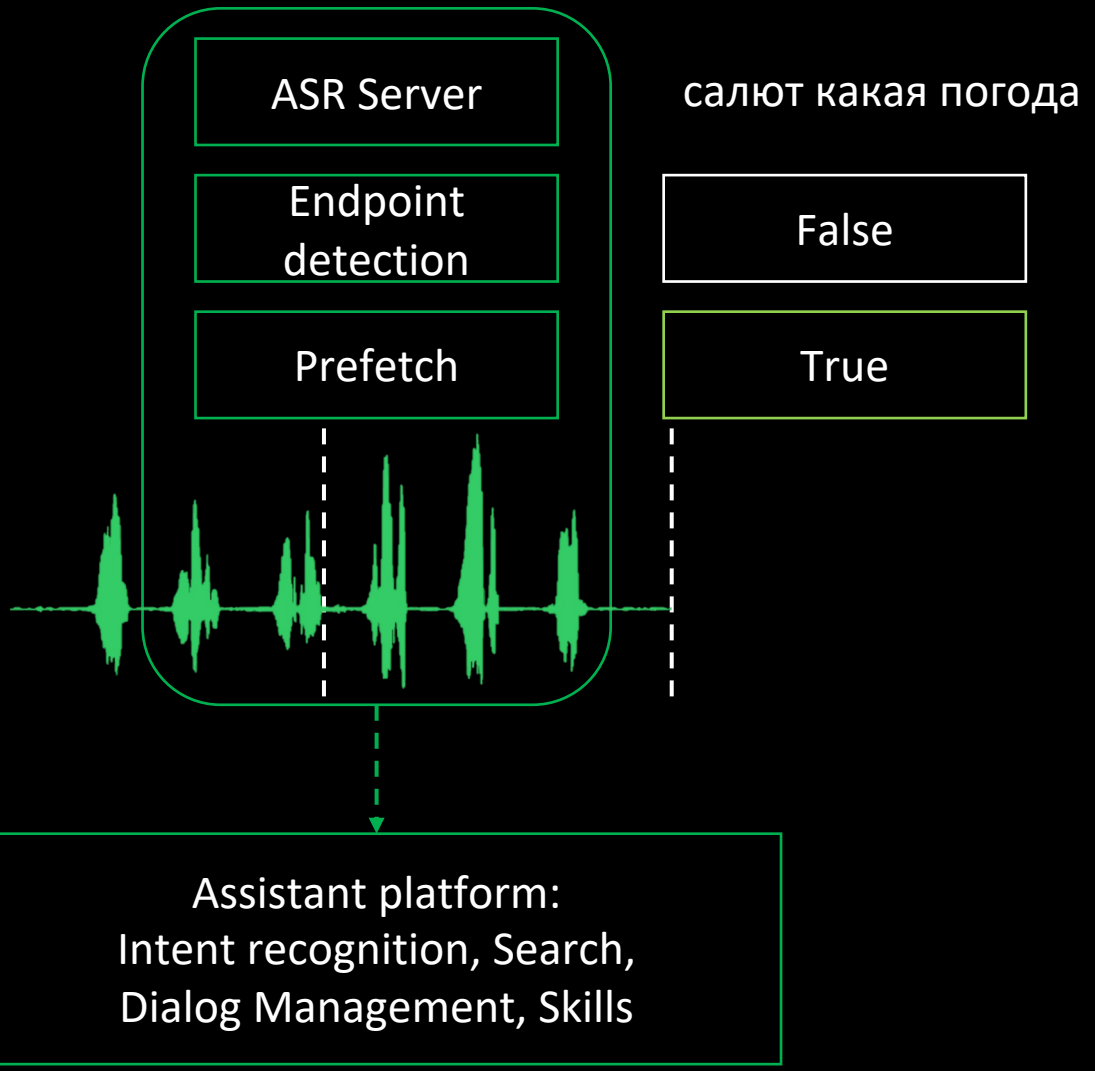


Assistant platform:
Intent recognition, Search,
Dialog Management, Skills

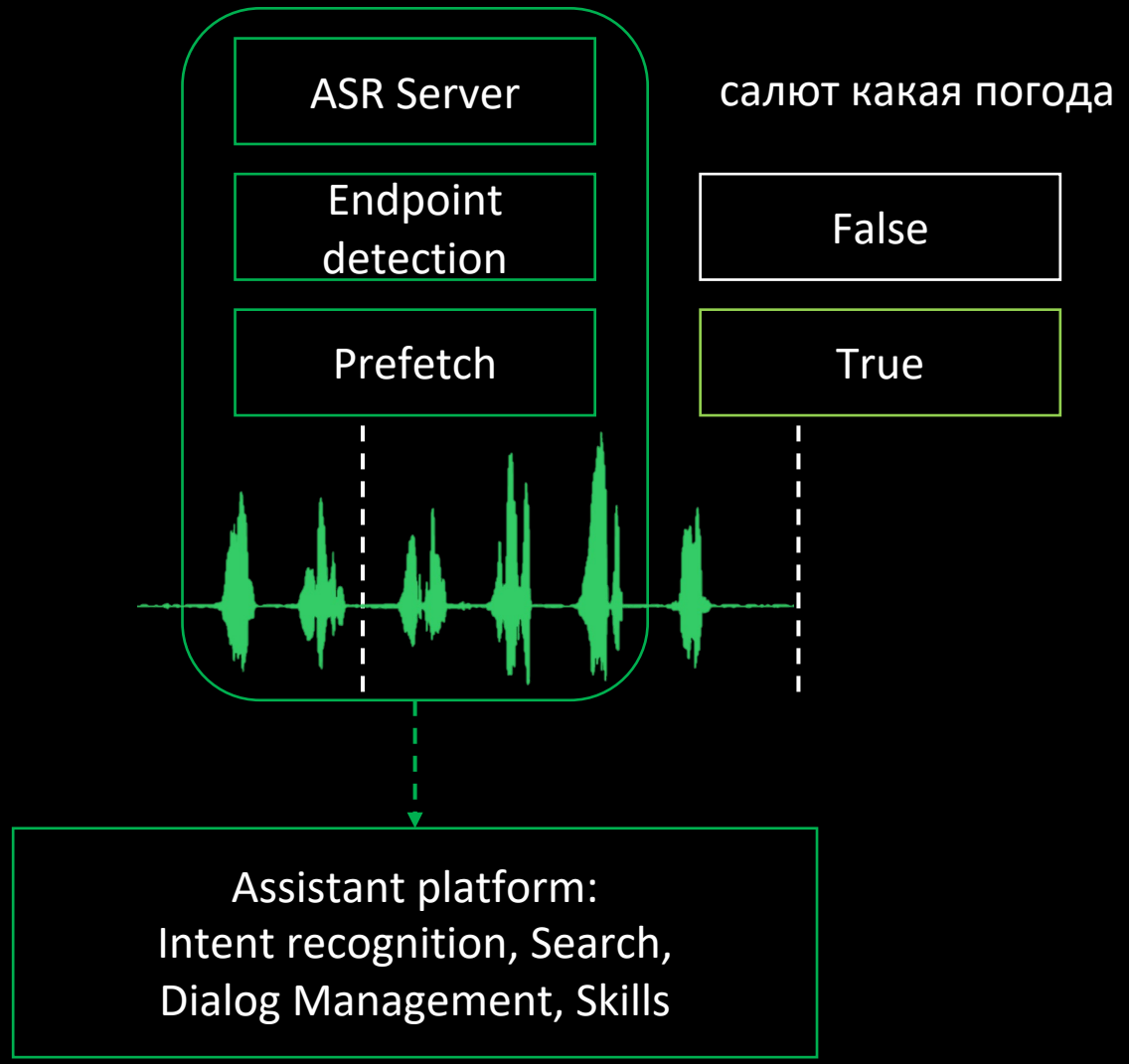
User perceived latency: prefetch recognition



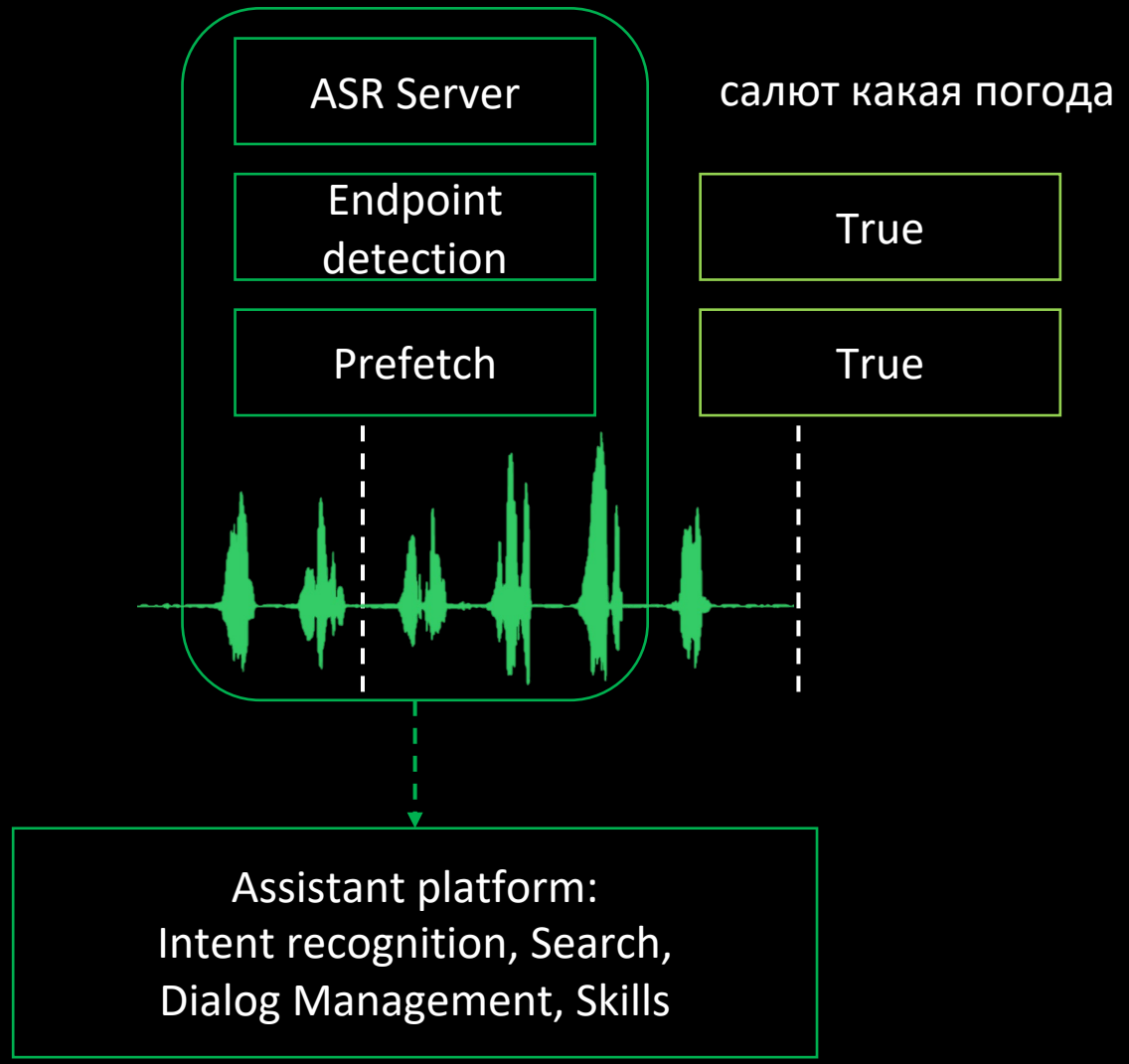
User perceived latency: prefetch recognition



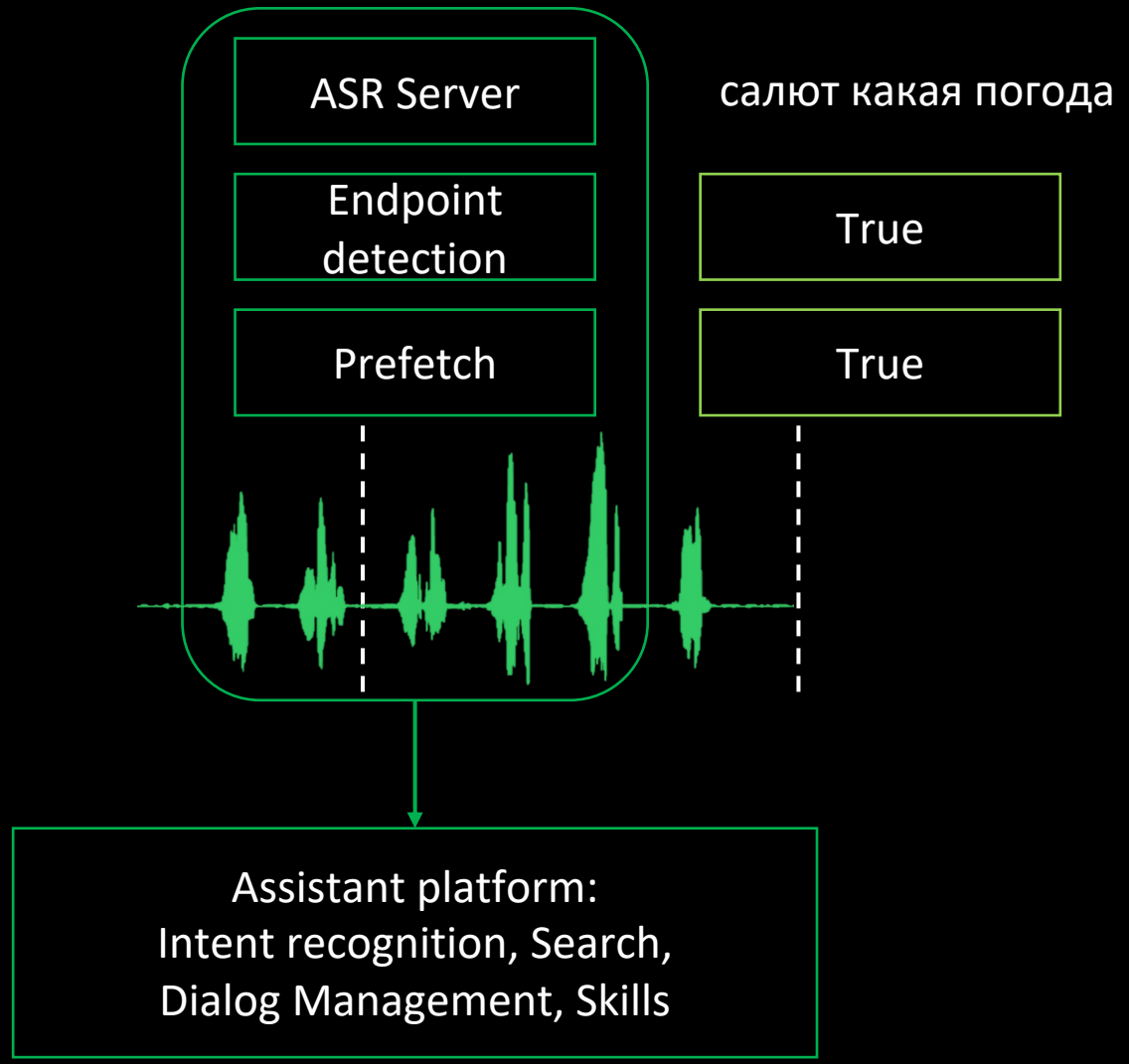
User perceived latency: prefetch recognition



User perceived latency: prefetch recognition



User perceived latency: prefetch recognition



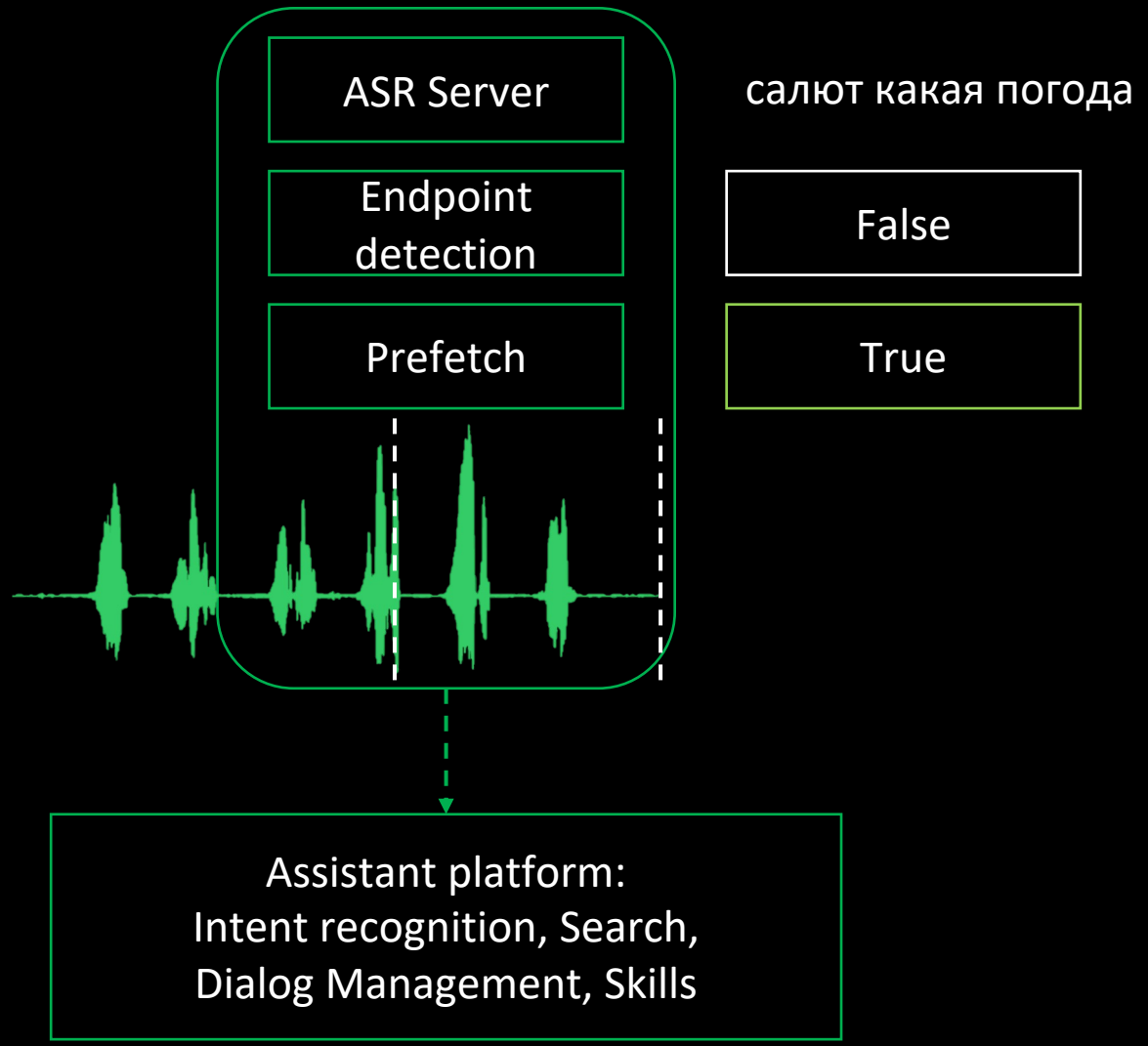
User perceived latency: prefetch recognition

Основная задача в рамках Voice Assistant Pipeline
- Оценка завершенности частично распознанного запроса

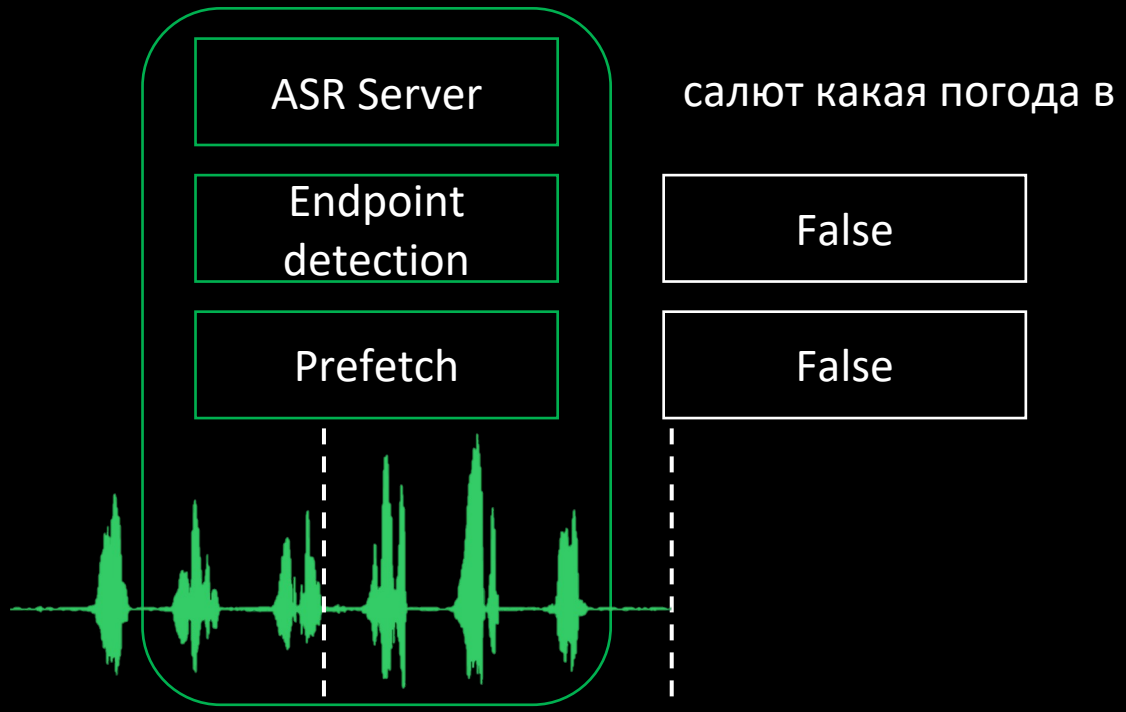
Преимущества:
- Снижаем user perceived latency за счет уменьшения latency на уровне Assistant Platform

Недостатки:
- Дополнительная нагрузка на Assistant Platform

User perceived latency: prefetch recognition

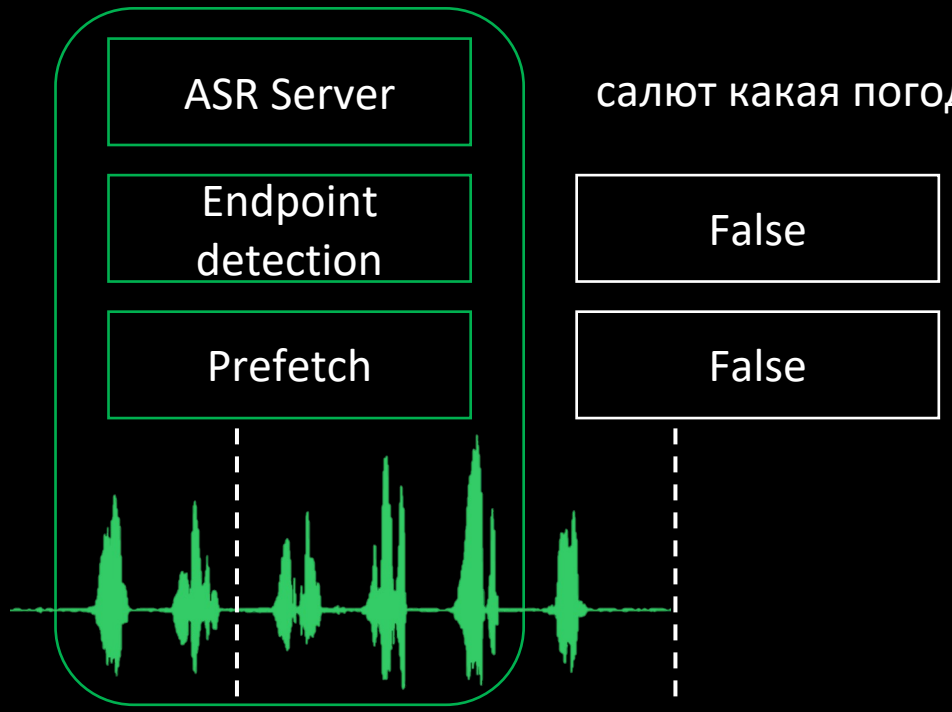


User perceived latency: prefetch recognition



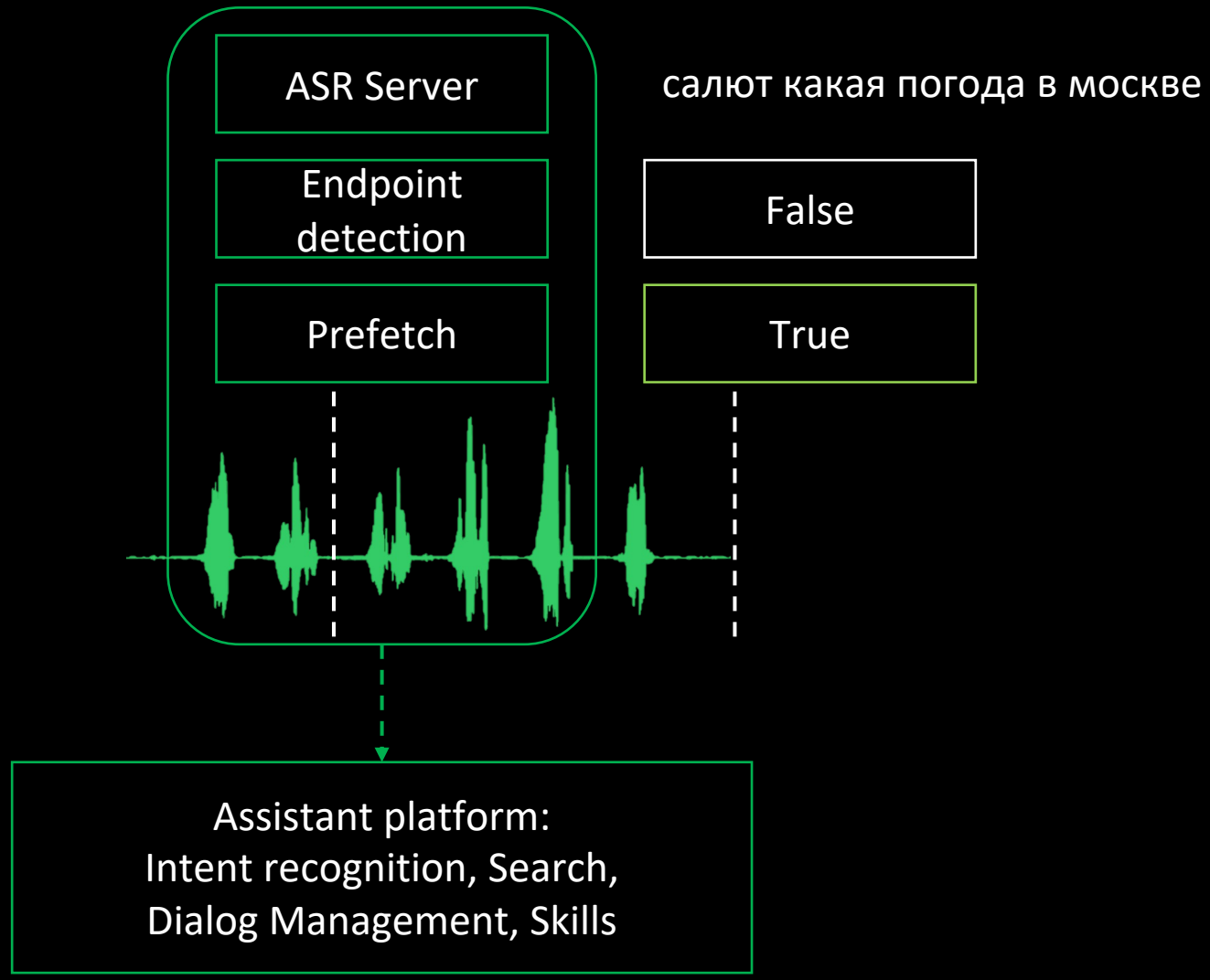
Assistant platform:
Intent recognition, Search,
Dialog Management, Skills

User perceived latency: prefetch recognition

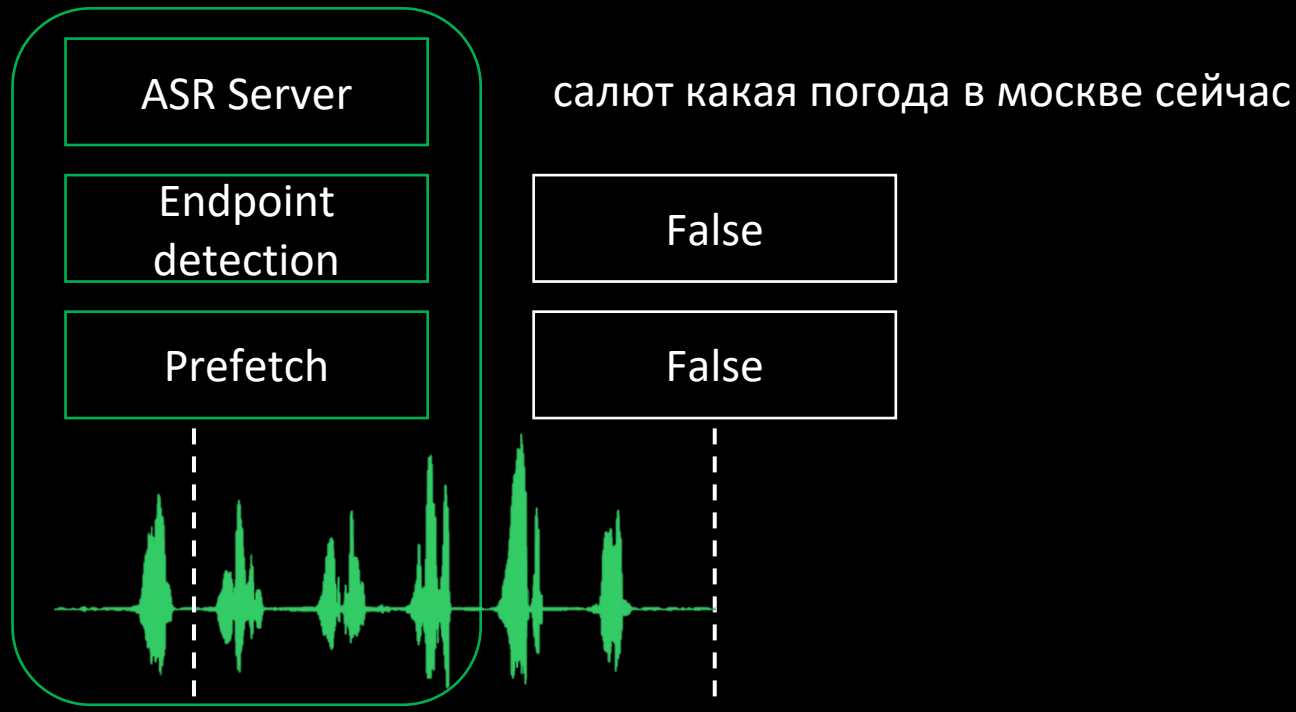


Assistant platform:
Intent recognition, Search,
Dialog Management, Skills

User perceived latency: prefetch recognition

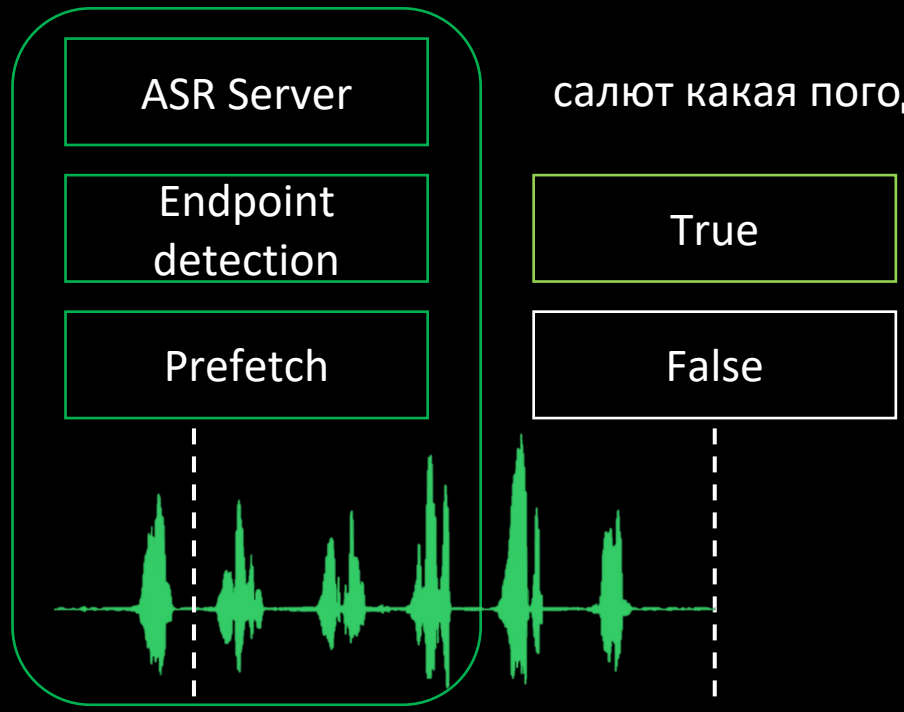


User perceived latency: prefetch recognition



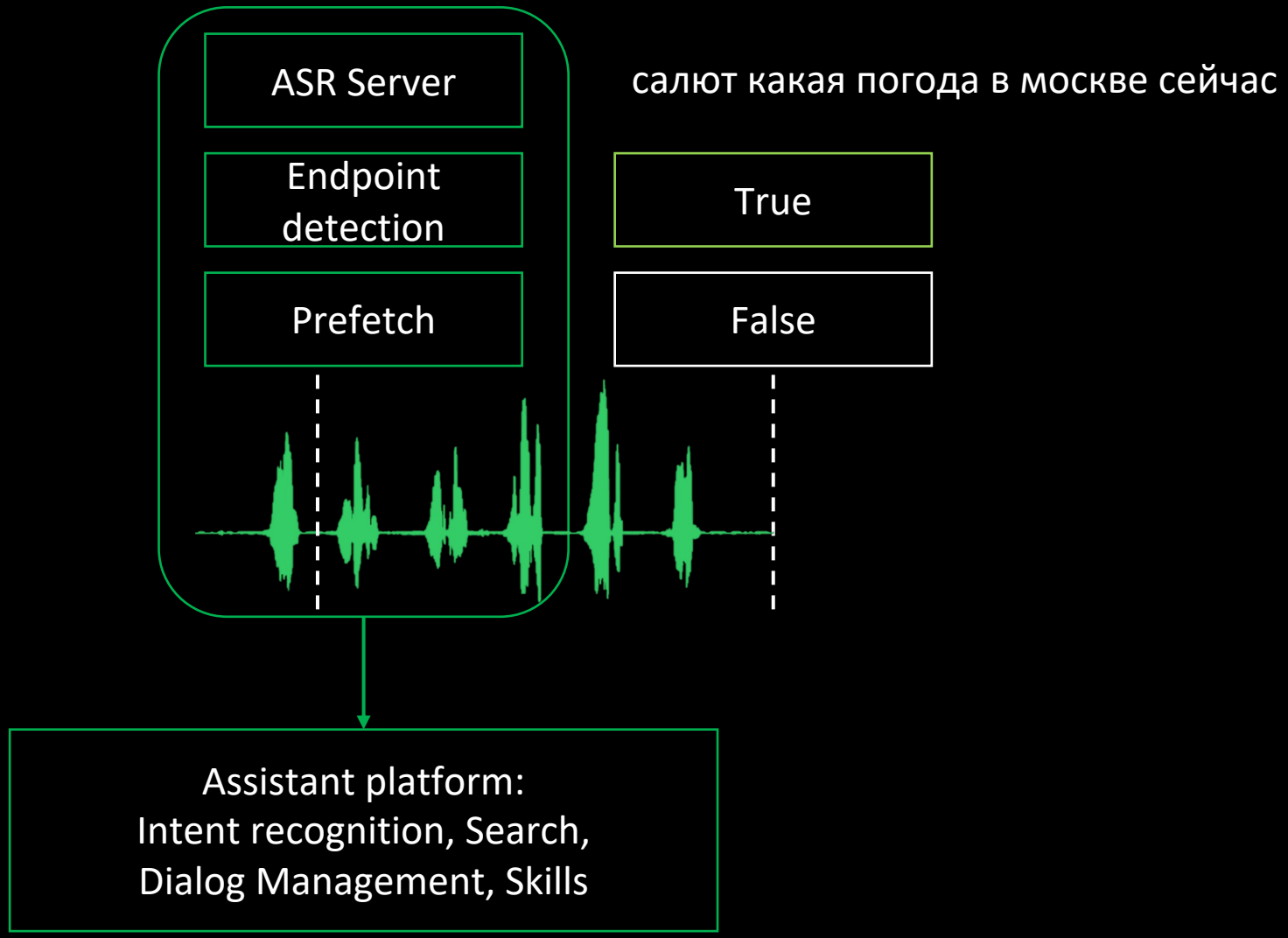
Assistant platform:
Intent recognition, Search,
Dialog Management, Skills

User perceived latency: prefetch recognition



Assistant platform:
Intent recognition, Search,
Dialog Management, Skills

User perceived latency: prefetch recognition



Итоги:

- Voice assistant pipeline
- User perceived latency
  - Keyword detection
    - Подходы: on-device, cascade system, complex cascade system
    - Метрики: FAR, FRR, FAh
  - Endpoint detection
    - Подходы: audio / text only, audio & text
    - Метрики: WERR, EEPR, latency
  - Prefetch recognition