What's New in Core Audio for iOS

Session 602

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Introduction

- Overview of new audio features in iOS 7
- Focus on one exciting new technology

Audio Input Selection

NEW

- Select among available audio inputs
- Choose which microphone on multi-mic devices
- Set microphone polar pattern
    - Achieves directivity through beam forming processing
    - e.g., cardioid, subcardioid
- See `<AVFoundation/AVAudioSession.h>`

Multichannel Audio Enhancements

NEW

- Discover maximum number of input and output channels
- Set preferred number of input and output channels
- Get audio channel labels
- See `<AVFoundation/AVAudioSession.h>`

Open AL Extensions

NEW

- Per-source spatialization rendering quality
  - Improved high-quality rendering algorithm
  - Render to multichannel output hardware
- Output capture
- See `<OpenAL/oalMacOSX_OALExtensions.h>`

Audio Queue Time-Pitch Capabilities

NEW

- Set playback rate
- Adjust playback pitch
- See `<AudioToolbox/AudioQueue.h>`

Audio Recording Permission

NEW

- Recording now requires user approval
- One-time approval remembered for each application
- Changeable in Settings
- Silence until permission is granted
- Triggered by use of AVAudioSession categories that enable recording
- API for application control

```
{
    ...
    [[AVAudioSession sharedInstance] requestRecordPermission];
    ...
}
```

Deprecated Audio Session C API

- Use AVAudioSession
- See `<AVFoundation/AVAudioSession.h>`

New in iOS 7
Summary

- Audio input selection
- Multichannel audio enhancements
- Open AL extensions
- Audio Queue time-pitch capabilities
- Audio recording permission
- Audio Session C API officially deprecated—Use AVAudioSession

New in iOS 7

Summary

- Audio input selection
- Multichannel audio enhancements
- Open AL extensions
- Audio Queue time-pitch capabilities
- Audio recording permission
- Audio Session C API officially deprecated—Use AVAudioSession
- Inter-app audio

Inter-App Audio

NEW

- Stream audio between apps in real-time
- Built on familiar APIs

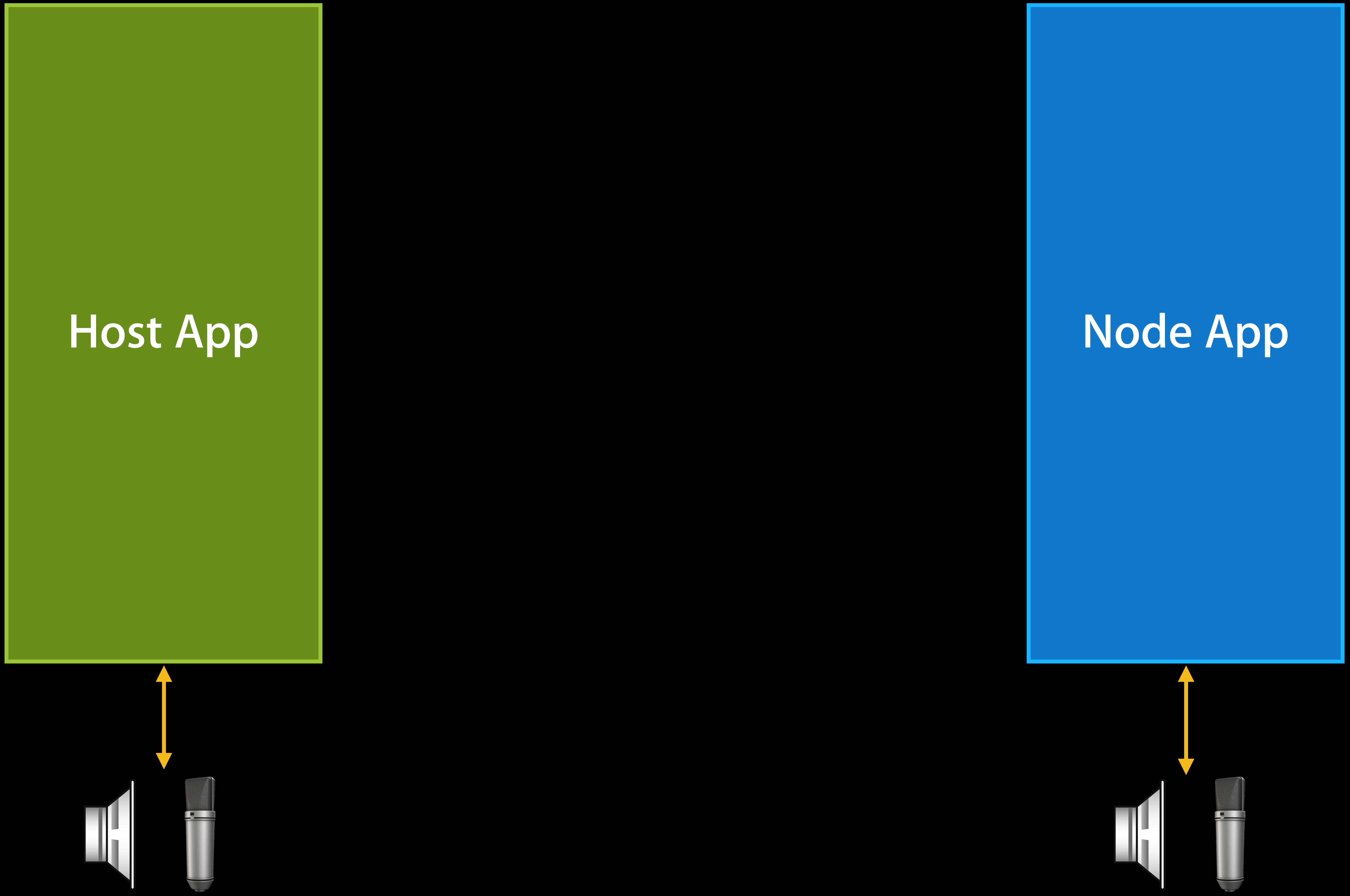
Demo

Alec Little
GarageBand

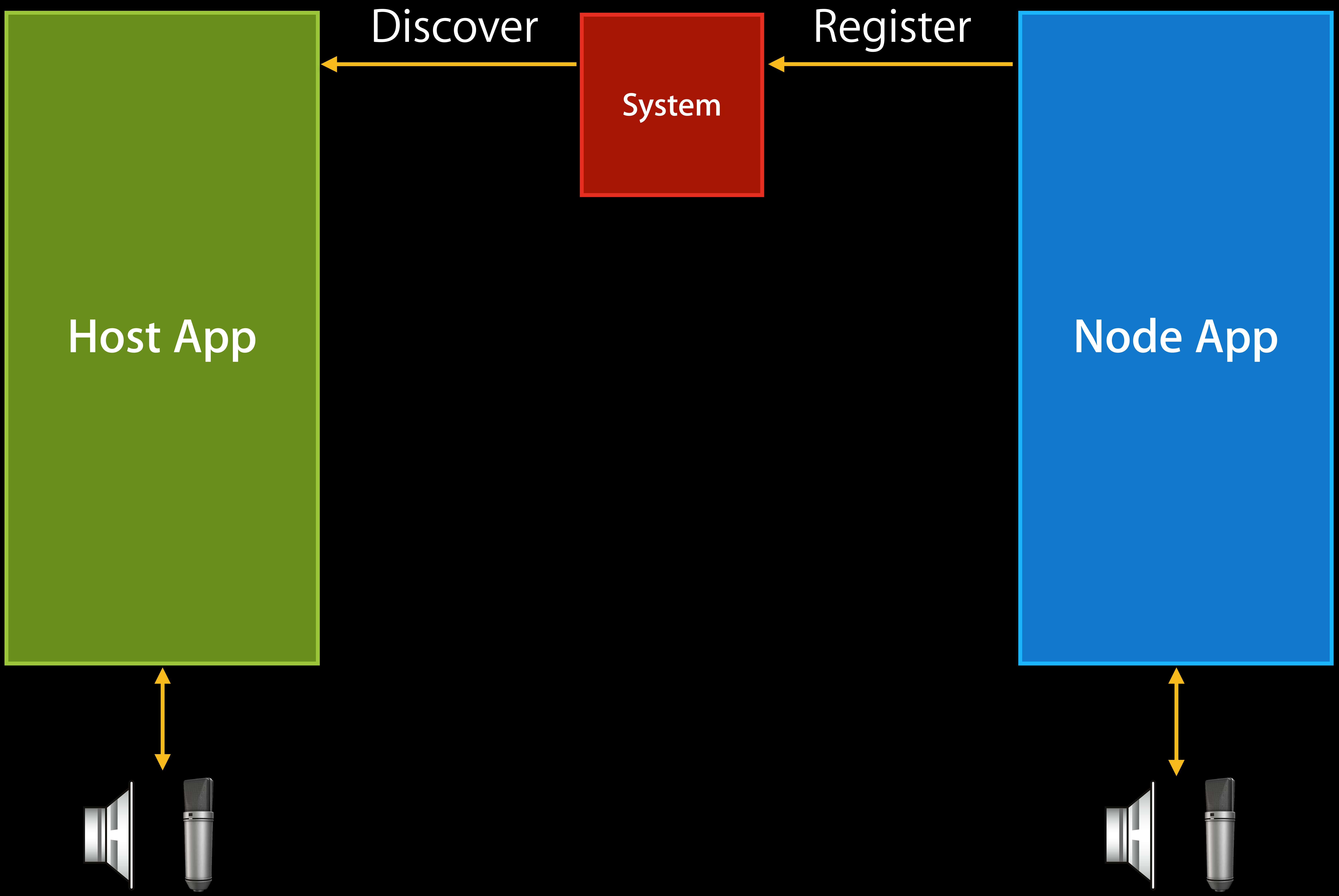
Inter-App Audio in Detail

Doug Wyatt
Core Audio Plumber

API Overview



API Overview



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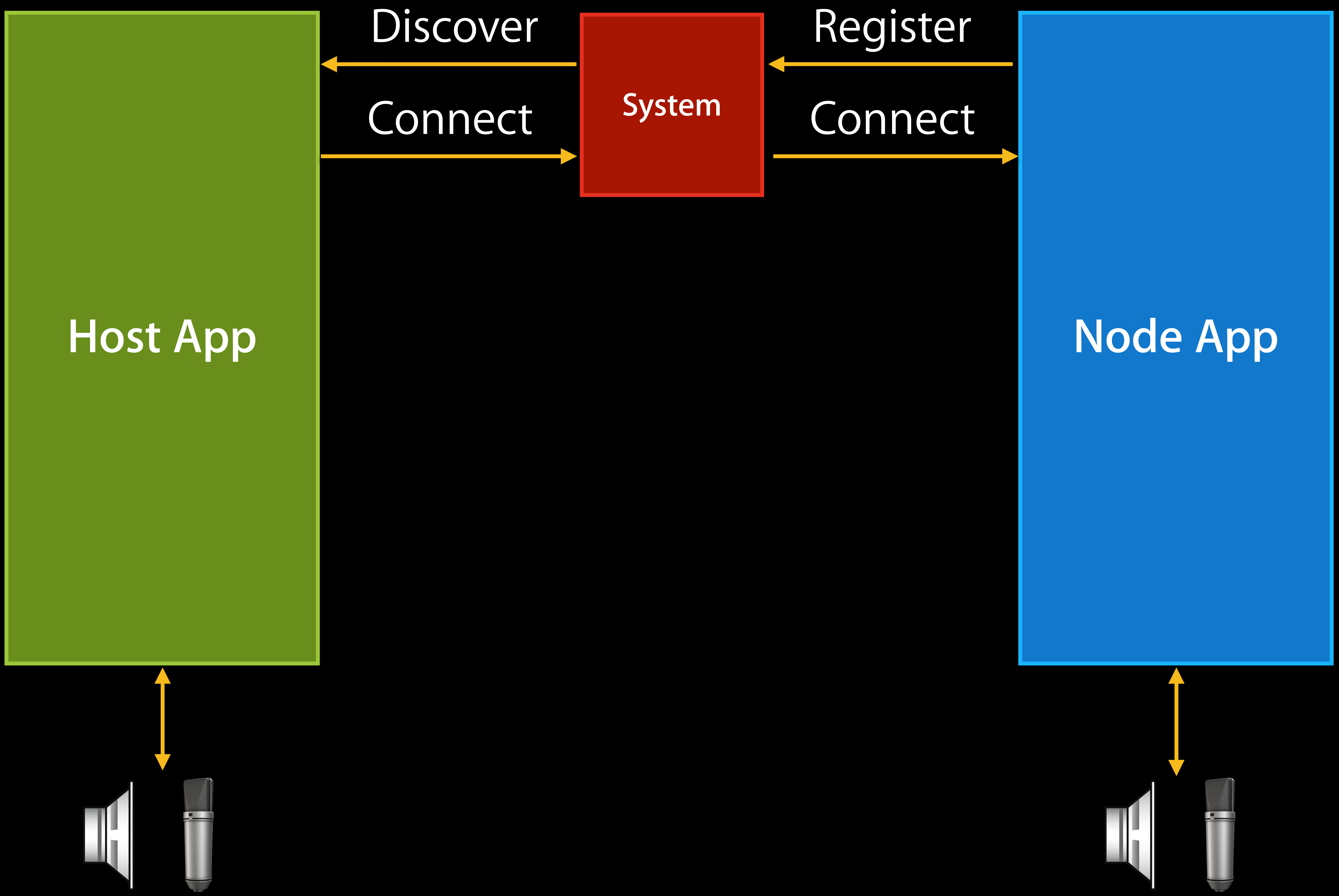

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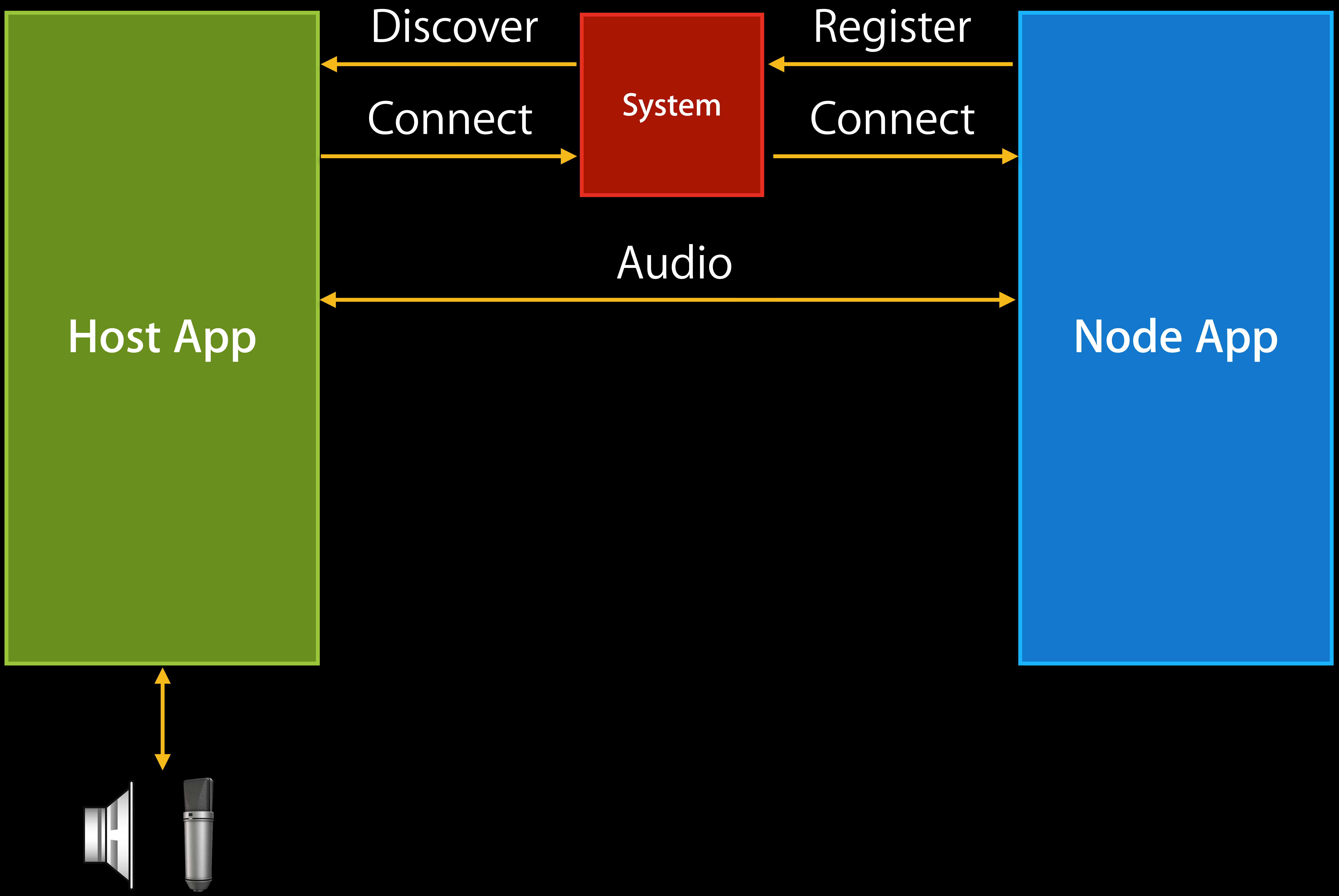

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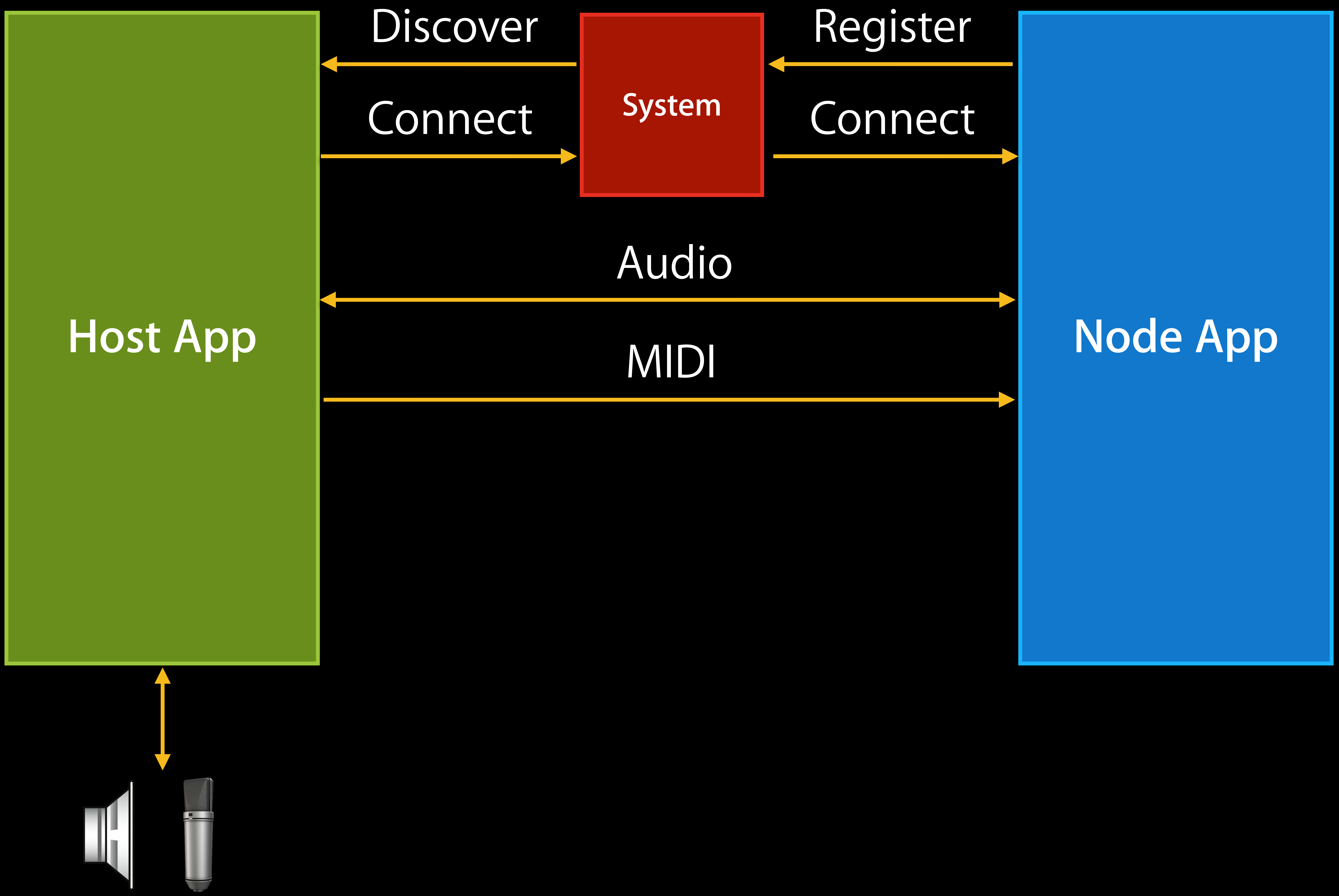

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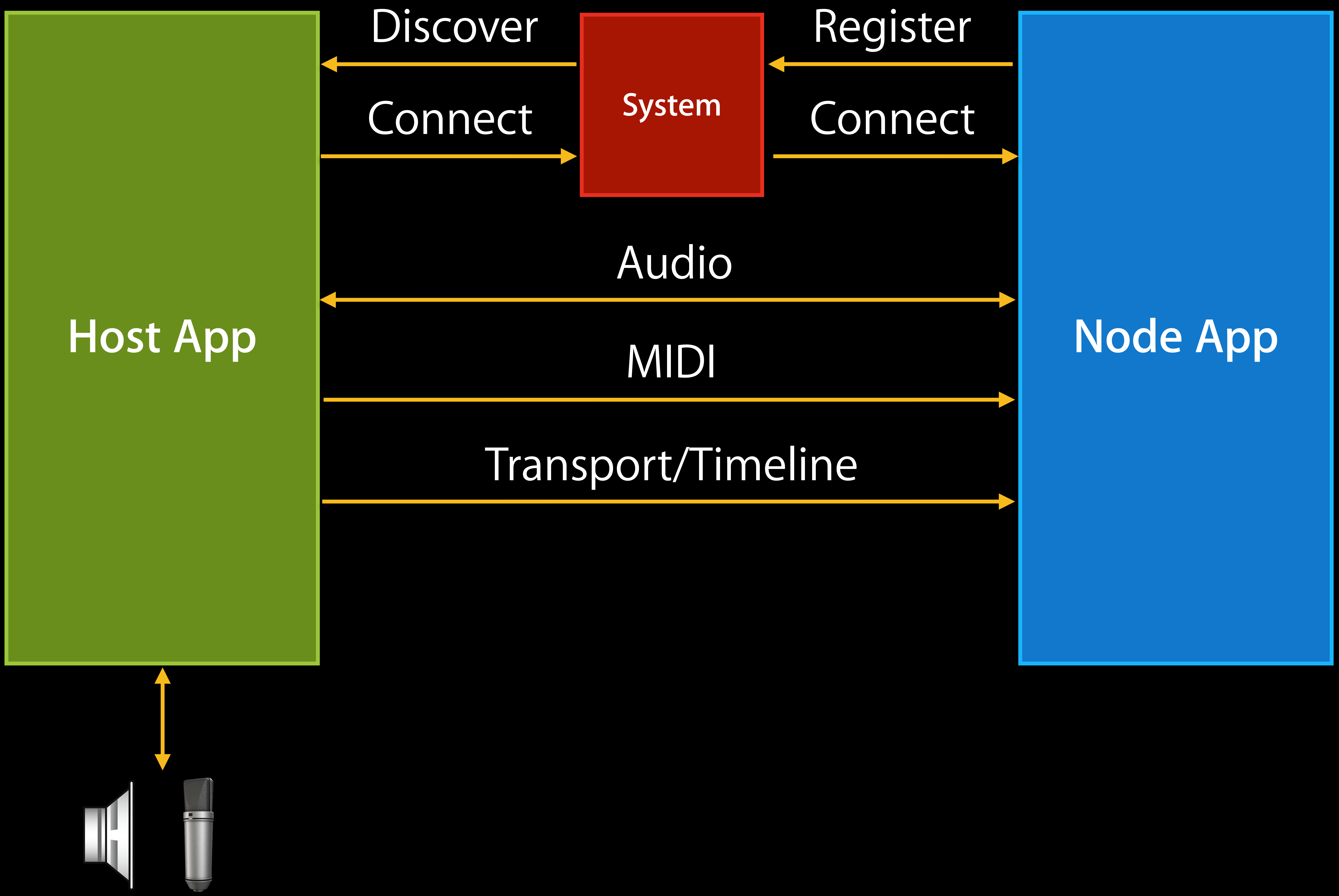

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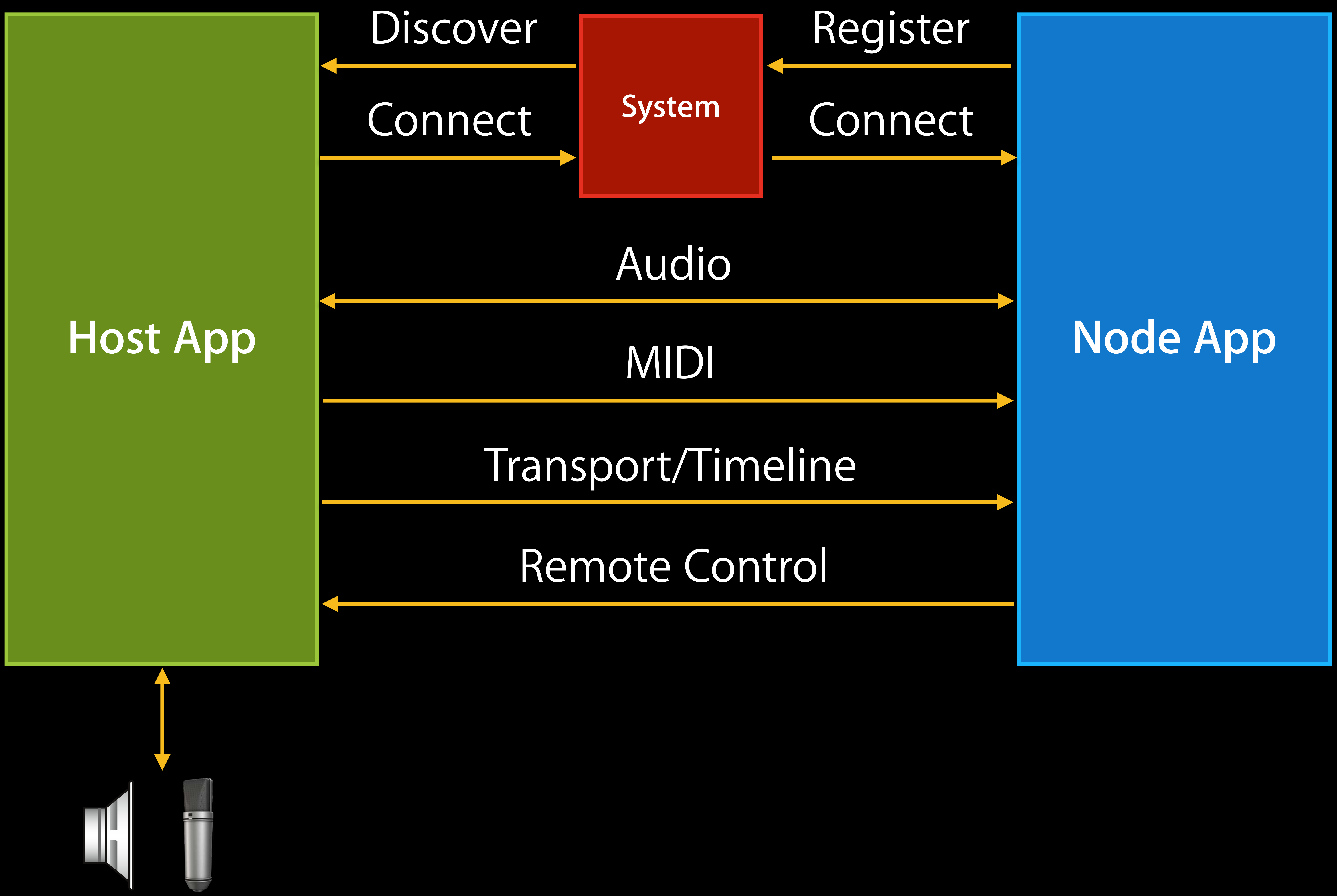
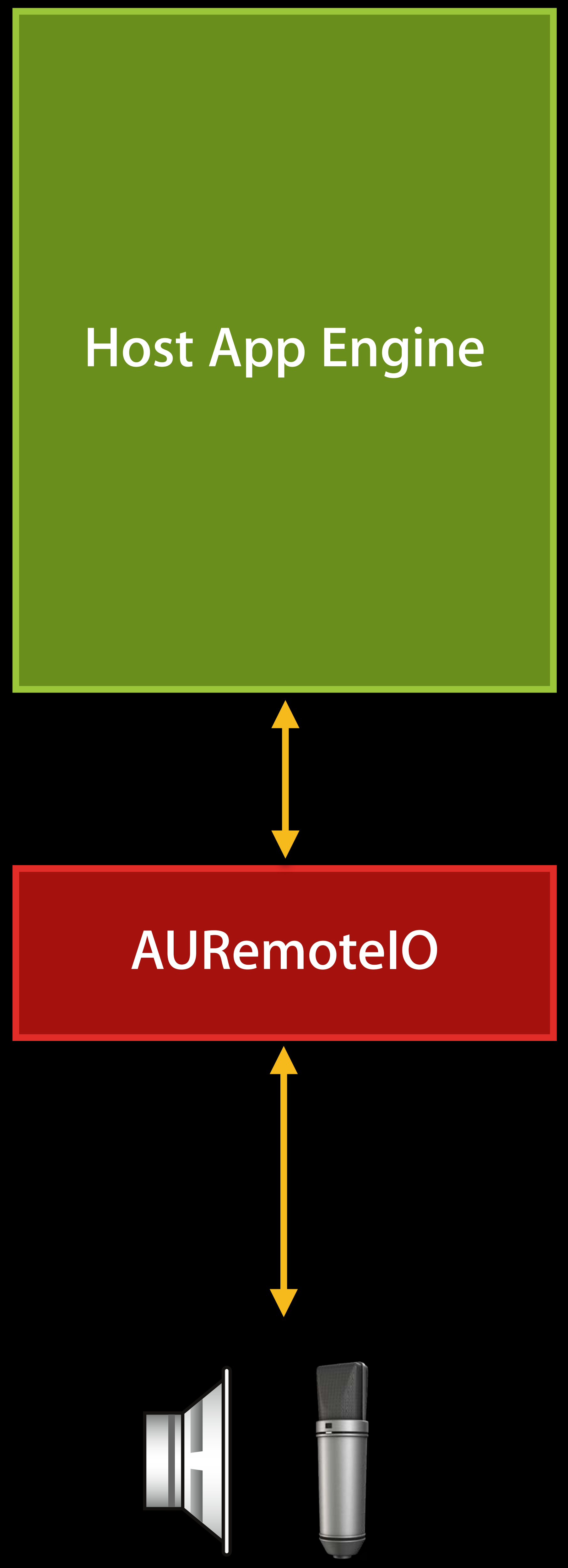


Introduction

Host app



Introduction

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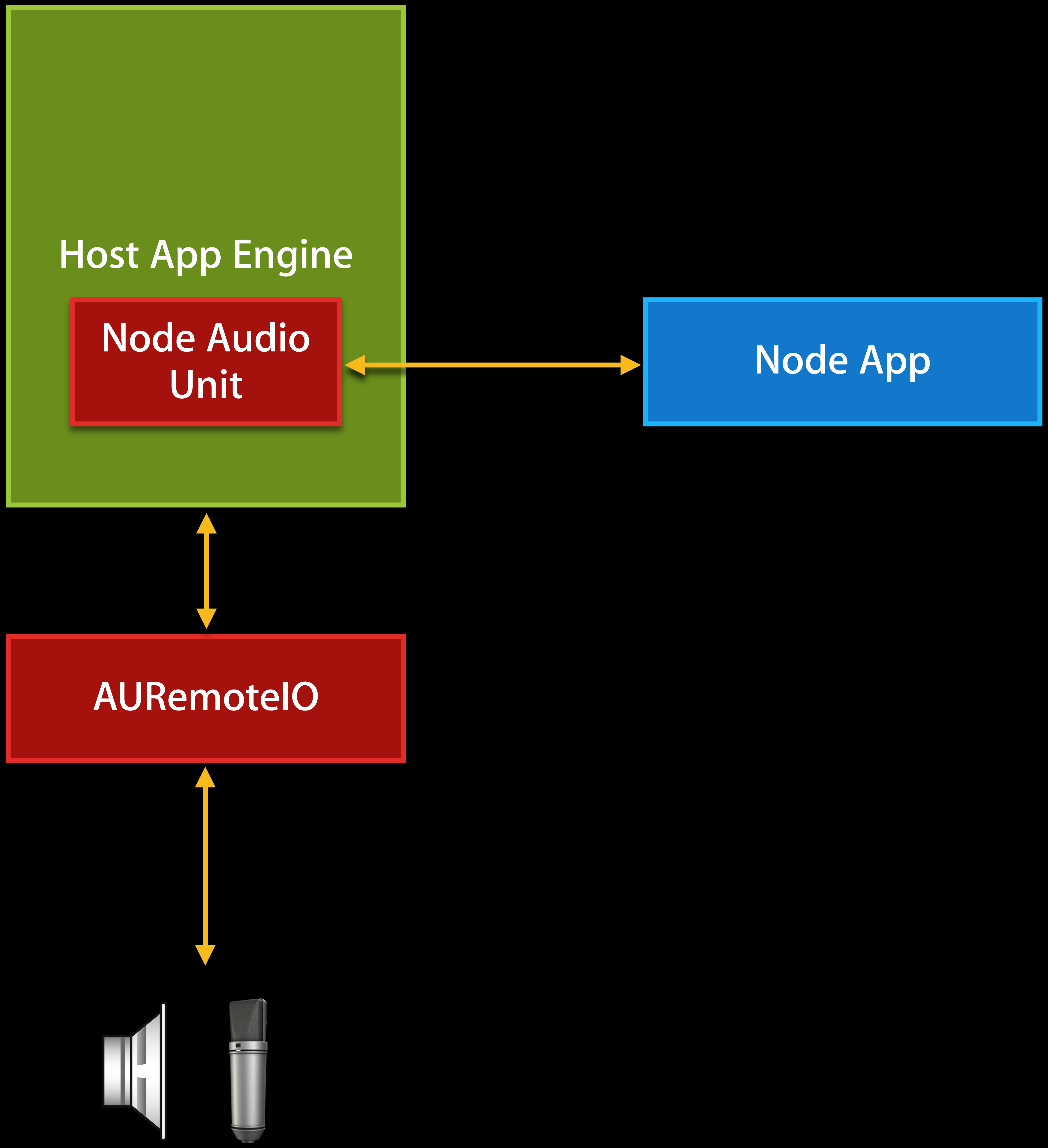
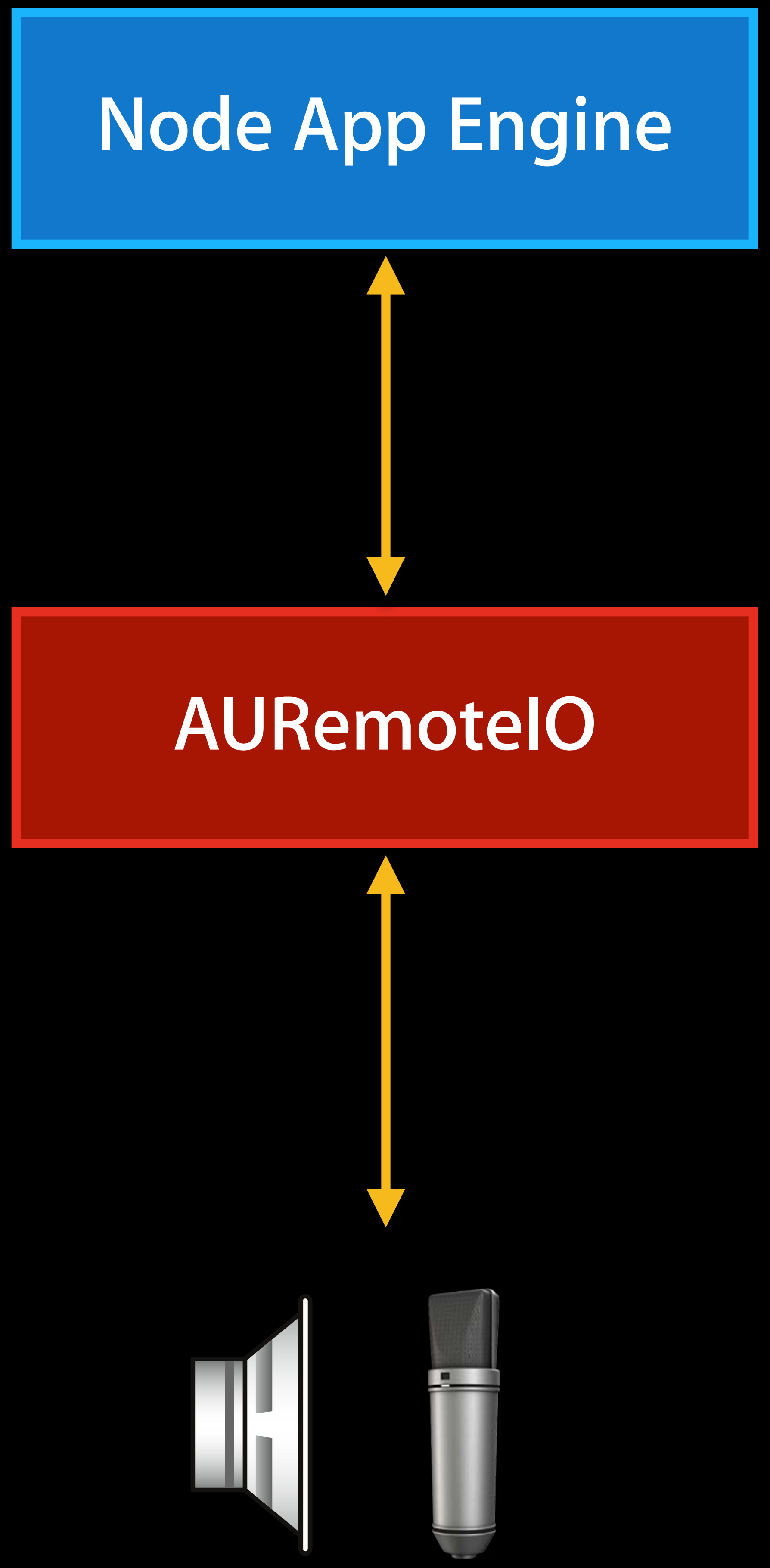


Introduction

Node app



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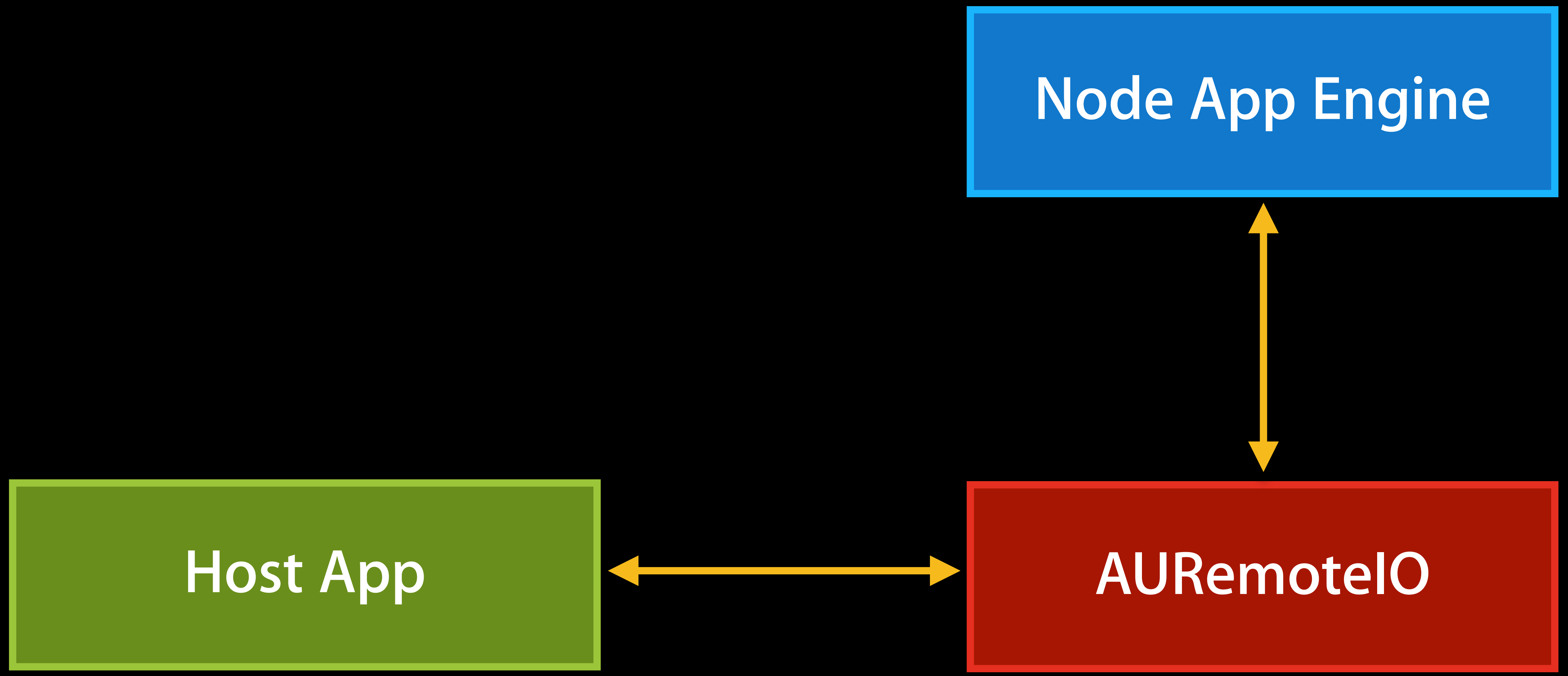


Introduction

- Extensions to AudioUnit.framework API
- Host sees node as AudioUnit
- Node’s I/O unit redirected to host

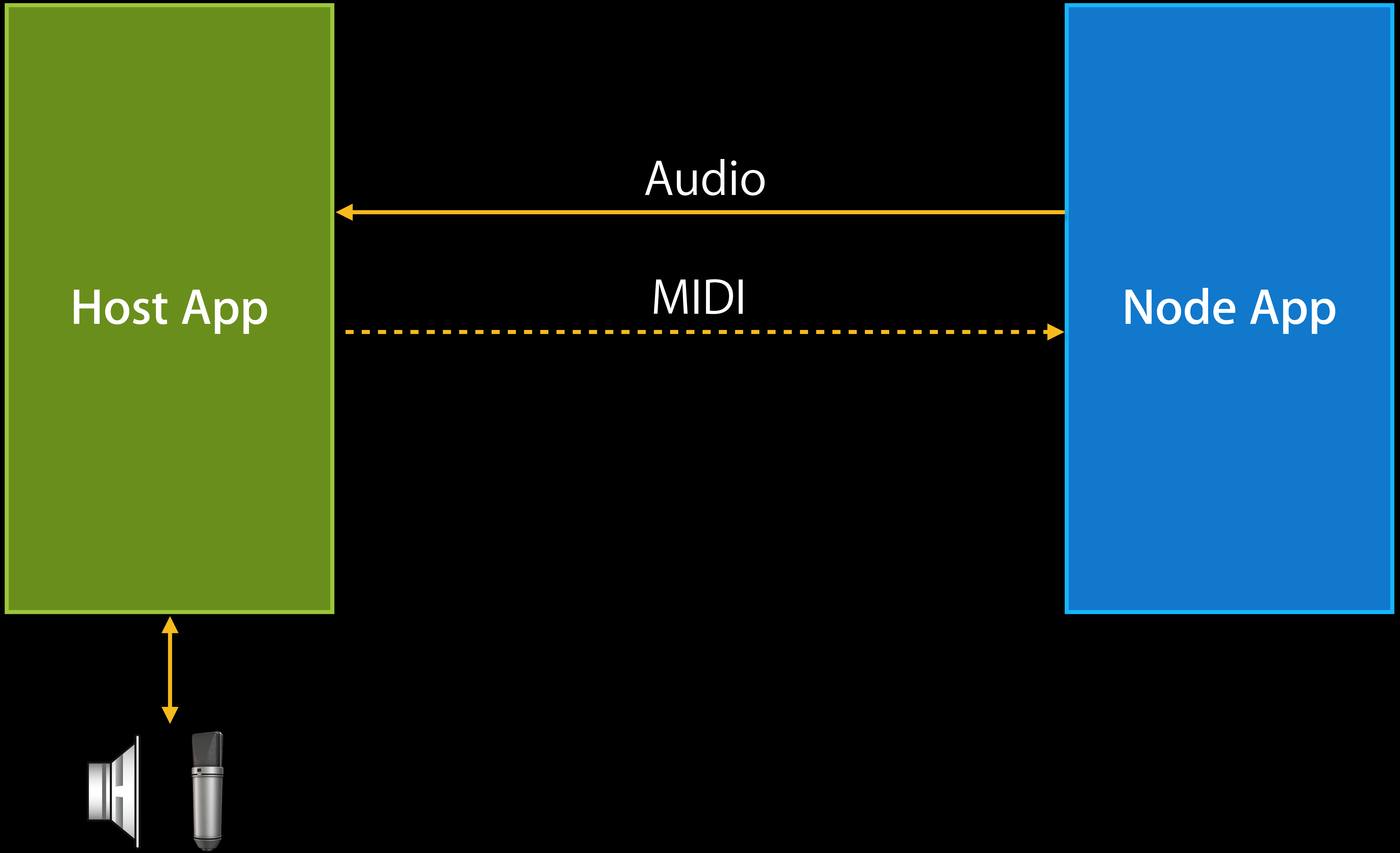
Introduction

New AudioUnit types

Audio Component Type	Input (from Host)	Output
kAudioUnitType_RemoteGenerator	-	audio
kAudioUnitType_RemoteInstrument	MIDI	audio
kAudioUnitType_RemoteEffect	audio	audio
kAudioUnitType_RemoteMusicEffect	audio and MIDI	audio

One Node App, Multiple Components

Generator or instrument



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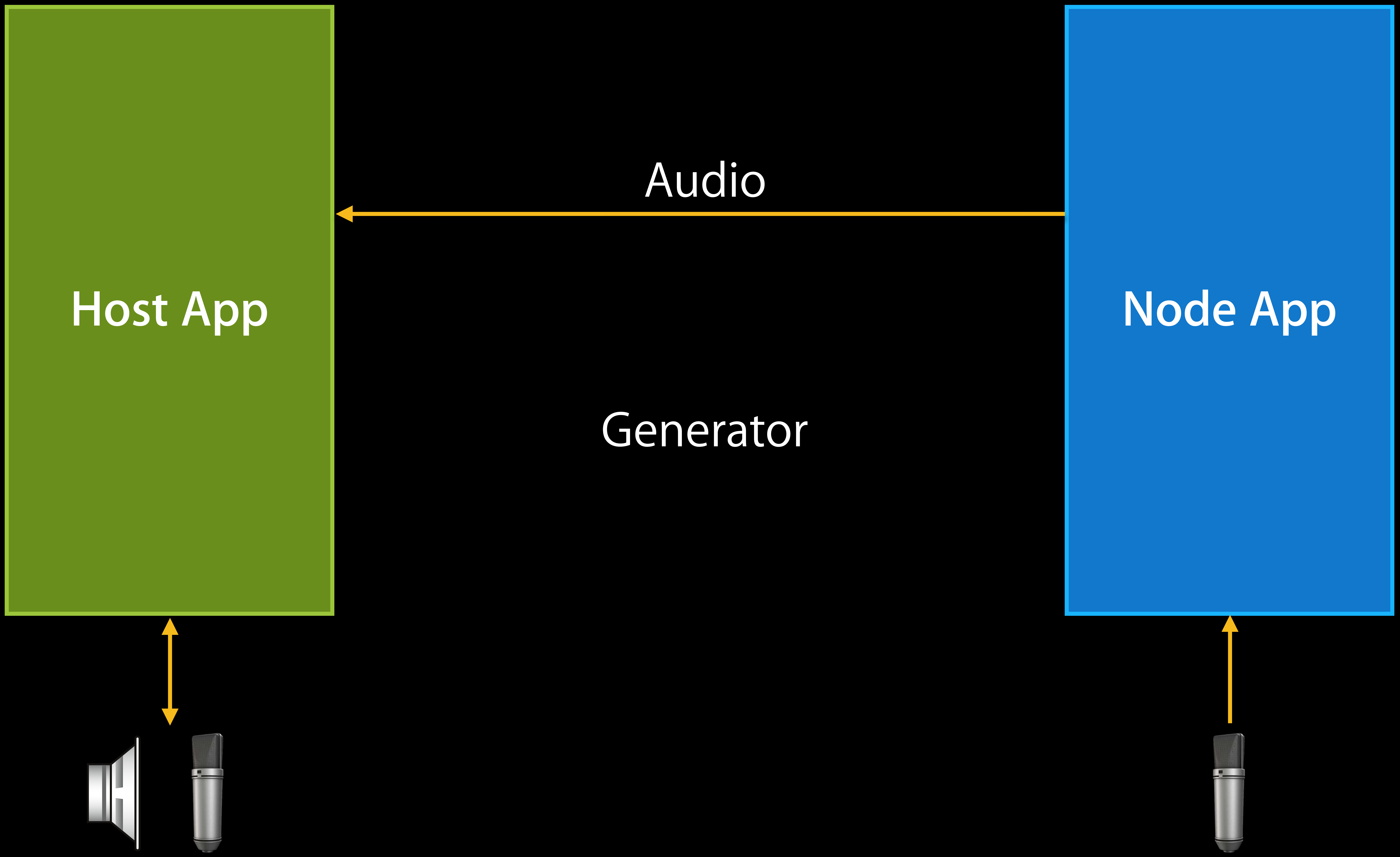

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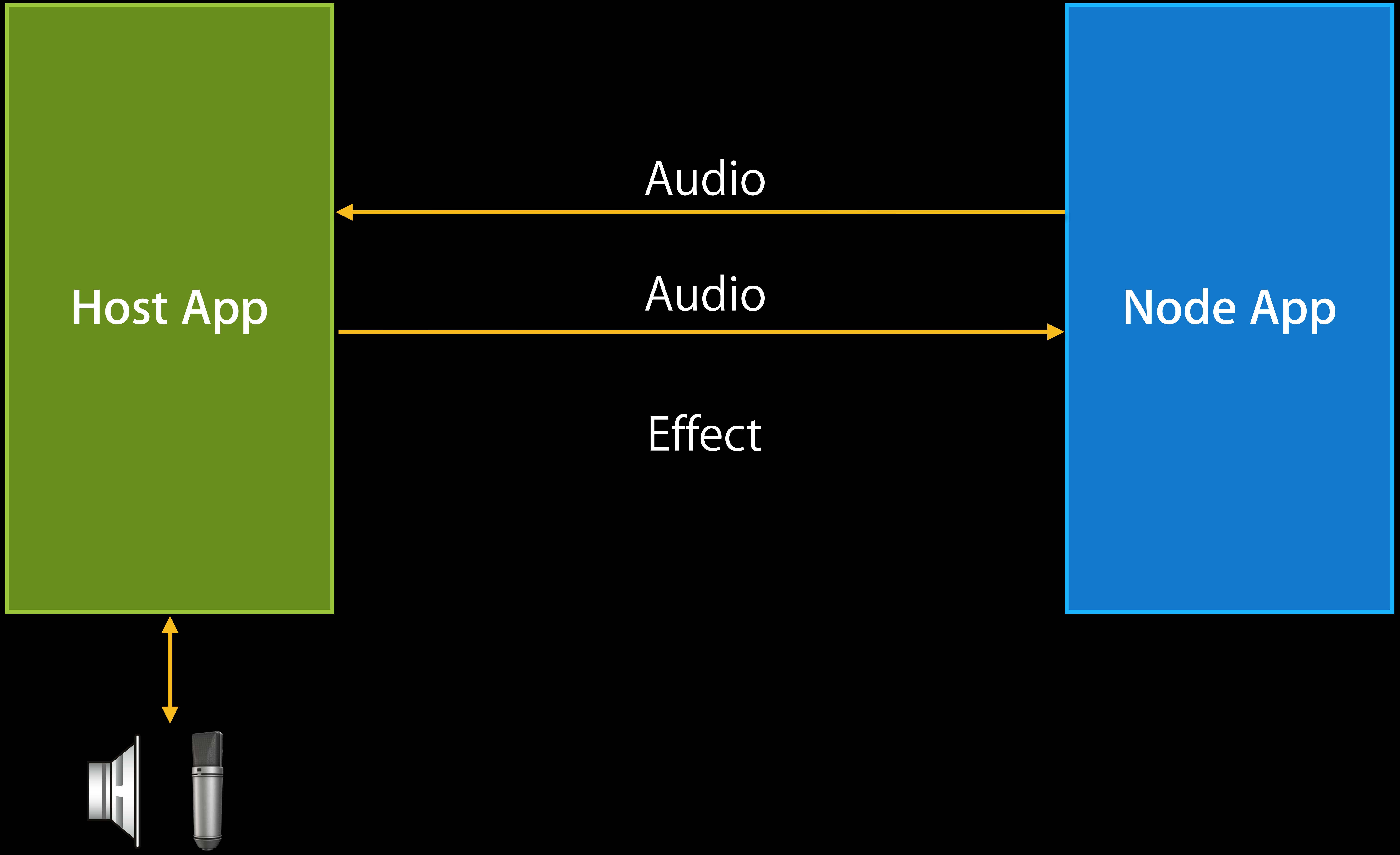
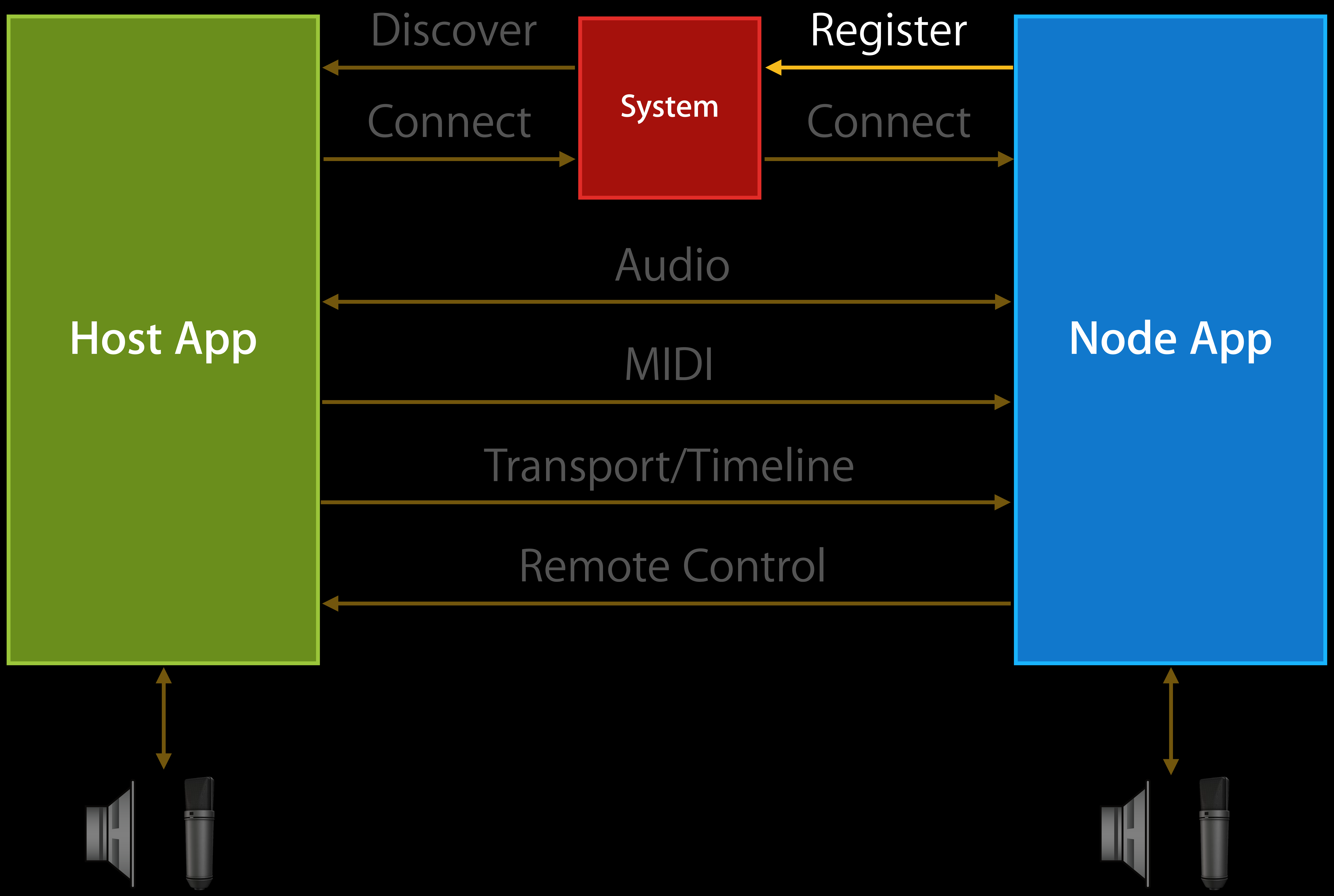


Introduction

Requirements

- Available on most iOS 7-compatible devices
    - (Except iPhone 4: API’s fail quietly)
- “inter-app-audio” entitlement (all)
- “audio” in UIBackgroundModes (hosts, nodes that access mic)
- AVAudioSessionCategoryOptionMixWithOthers (nodes)

Registering a Node App



Registering a Node App

- Register via Info.plist “AudioComponents”
    - Makes app launchable
- AudioOutputUnitPublish
    - “Checks in” the registration

Registering a Node App

AudioComponents entry in Info.plist

```
<key>AudioComponents</key>
<array>
    <dict>
        <key>type</key>
        <string>aurg</string>
        <key>subtype</key>
        <string>ACgn</string>
        <key>manufacturer</key>
        <string>ACME</string>
        <key>name</key>
        <string>Acme: SineGenerator</string>
        <key>version</key>
        <integer>1</integer>
    </dict>
</array>
```

Registering a Node App

Create and publish the I/O unit

```
  // create the AURemoteIO I/O unit

AudioComponentDescription ioUnitDesc = { kAudioUnitType_Output,
kAudioUnitSubType_RemoteIO, kAudioUnitManufacturer_Apple, 0, 0 };

AudioComponent comp = AudioComponentFindNext(NULL, &ioUnitDesc);

err = AudioComponentInstanceNew(comp, &_ioUnit);

// publish the AURemoteIO

AudioComponentDescription generatorDesc = { kAudioUnitType_RemoteGenerator,
‘ACgn’, ‘ACME’, 0, 0 };

CFStringRef name = CFSTR(“Acme: SineGenerator”);

const UInt32 version = 1;

err = AudioOutputUnitPublish(&generatorDesc, name, version, _ioUnit);
```

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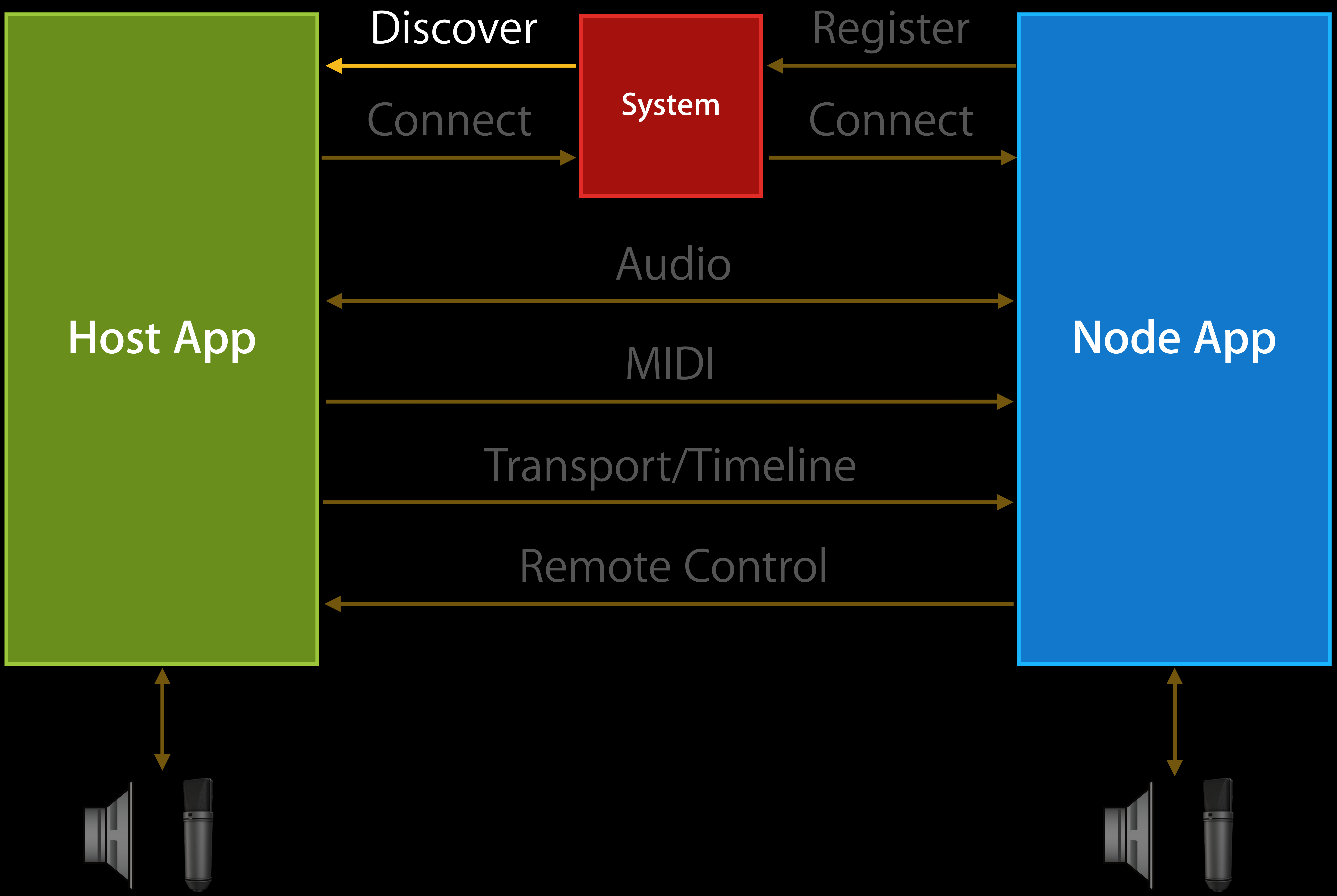
Registering a Node App

Publishing the I/O unit

- Must publish on launch
- Component descriptions, names, and versions must match
- Component name should be “Manufacturer: App name”

Node App Discovery (for Hosts)



Node App Discovery

For hosts

```
AudioComponentDescription searchDesc = { 0, 0, 0, 0, 0 }, foundDesc;
AudioComponent comp = NULL;

while (true) {
   comp = AudioComponentFindNext(comp, &searchDesc);
   if (comp == NULL) break;

   if (AudioComponentGetDescription(comp, &foundDesc) != noErr) continue;

   switch (foundDesc.componentType) {
      case kAudioUnitType_RemoteEffect:
      case kAudioUnitType_RemoteGenerator:
      case kAudioUnitType_RemoteInstrument:
      case kAudioUnitType_RemoteMusicEffect:
      // found a node
      ...
      break;
   }
}
```

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      ...
      break;
   }
}
```

Node App Discovery

Getting node information

```
RemoteAU *rau = [[RemoteAU alloc] init];
rau->_desc = foundDesc;
rau->_comp = comp;

AudioComponentCopyName(comp, (CFStringRef *)&rau->_name);

rau->_image = [AudioComponentGetIcon(comp, 48) retain];

rau->_lastActiveTime = AudioComponentGetLastActiveTime(comp);

[_audioUnits addObject: rau];
```

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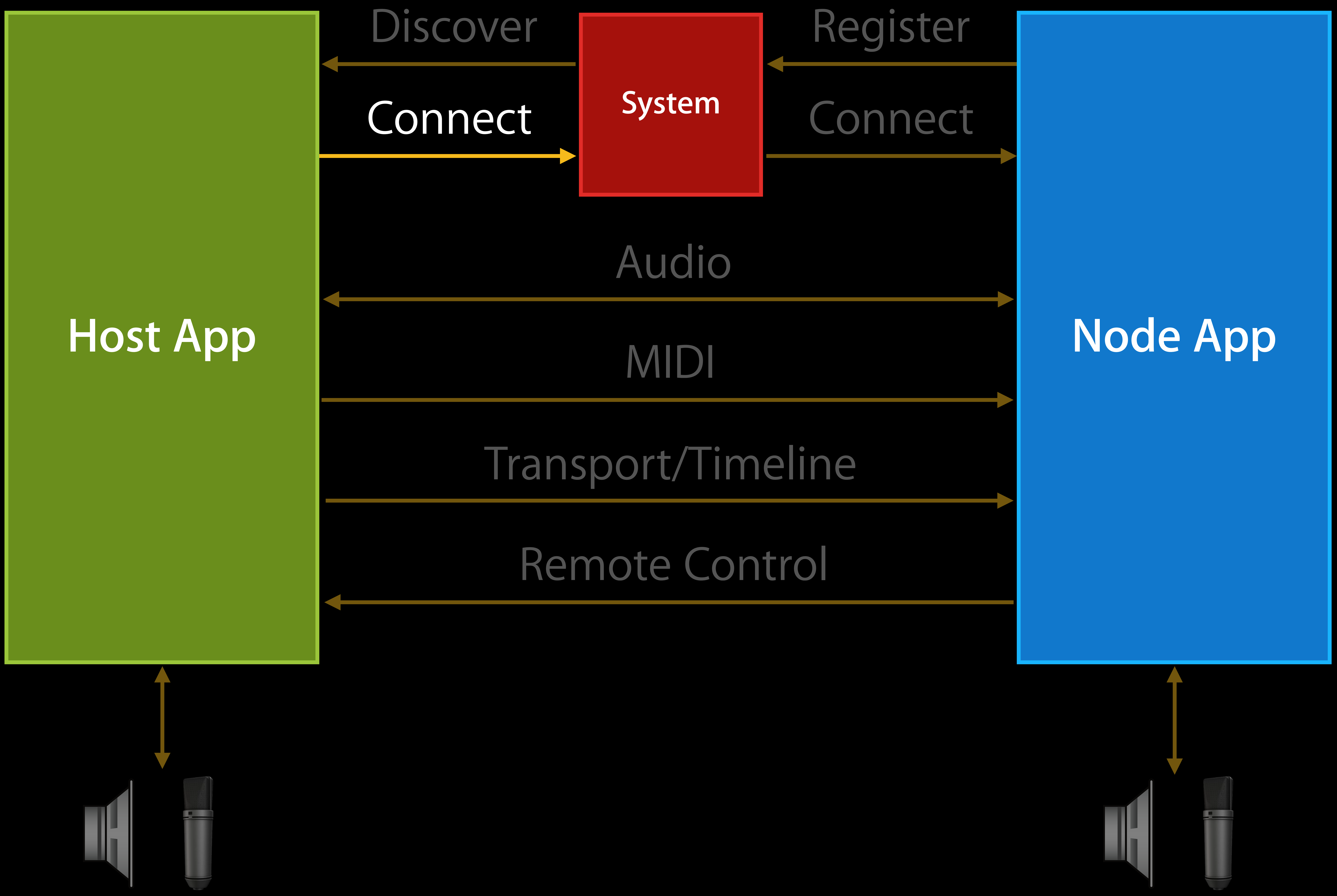
Node App Discovery

Observing registration changes

- Registrations change dynamically
  - When apps installed/deleted
  - When media services reset

```
NSNotificationCenter *nc = [NSNotificationCenter defaultCenter];
[nc addObserverForName:
  (NSString *) kAudioComponentRegistrationsChangedNotification
  object: nil queue: nil
  usingBlock:
    ^(NSNotification *) {
      [self refreshAUList];
    }
];
```

Connecting to a Node



Connecting to a Node

```
AudioUnit myAudioUnit;
err = AudioComponentInstanceNew(comp, &myAudioUnit);
```

- Node app will be launched into background

Preparing a Node
Activate audio session

```
[[AVAudioSession sharedSession] setActive: YES];
```

- Sample rate, channel count

Preparing a Node

Set stream formats

```
AudioStreamBasicDescription format;

format.mChannelsPerFrame = 2; // stereo
format.mSampleRate = [AVAudioSession sharedSession].sampleRate;
format.mFormatID = kAudioFormatLinearPCM;
format.mFormatFlags = kAudioFormatFlagsNativeFloatPacked |
                      kAudioFormatFlagIsNonInterleaved;
format.mBytesPerFrame = format.mBytesPerPacket = sizeof(Float32);
format.mBitsPerChannel = 32;
format.mFramesPerPacket = 1;

AudioUnitSetProperty(myAudioUnit, kAudioUnitProperty_StreamFormat,
  kAudioUnitScope_Output, 0, &format, sizeof(format));

AudioUnitSetProperty(myAudioUnit, kAudioUnitProperty_StreamFormat,
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Preparing a Node

Connect input

- For effects
- From AudioUnit:
  - AUGraphConnectNodeInput
  - kAudioUnitProperty_MakeConnection
- From callback:
  - kAudioUnitProperty_SetRenderCallback
- Output

Preparing a Node

Disconnection

- Can happen automatically
  - Node terminates
  - Host fails to render
- Instance becomes “zombie”
- kAudioComponentErr_InstanceInvalidated

Preparing a Node

Disconnection callback

```
AudioUnitAddPropertyListener(myAudioUnit,
  kAudioUnitProperty_IsInterAppConnected,
  NodeConnectionListener, self);


void NodeConnectionListener(void *userData, AudioUnit myAudioUnit,
  AudioUnitPropertyID, AudioUnitScope, AudioUnitElement)
{
   UInt32 connected = 0, size = sizeof(connected);
   OSStatus err =
   AudioUnitGetProperty(myAudioUnit, kAudioUnitProperty_IsInterAppConnected,
     kAudioUnitScope_Global, 0,
     &connected, &size);
   if (err != noErr || connected == 0) {
      // Node disconnected
   }
}
```

Preparing a Node

Initialization

```
// Prepare for rendering
AudioUnitInitialize(myAudioUnit);
```

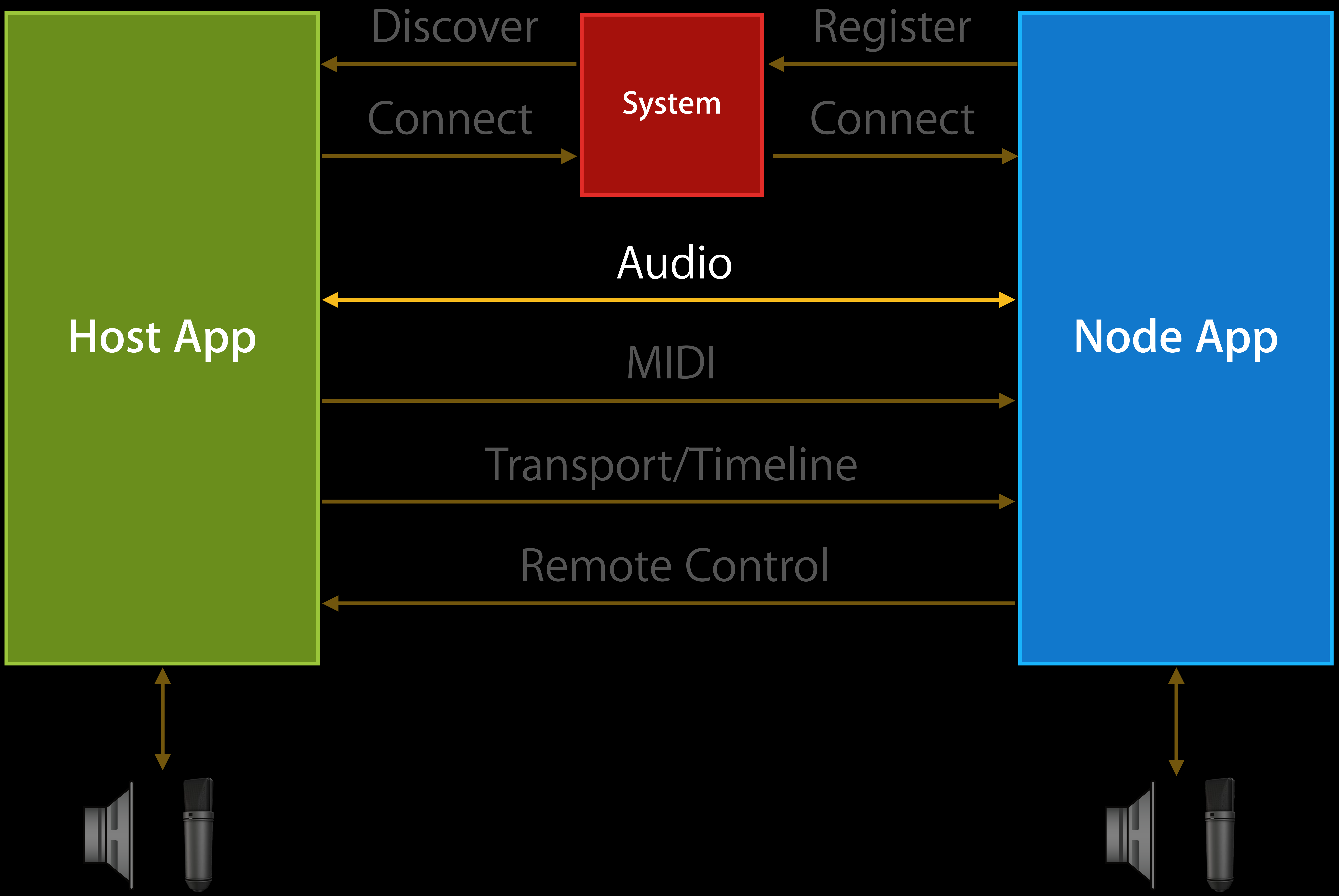
- Host must call AudioUnitRender regularly

Preparing a Node

Summary

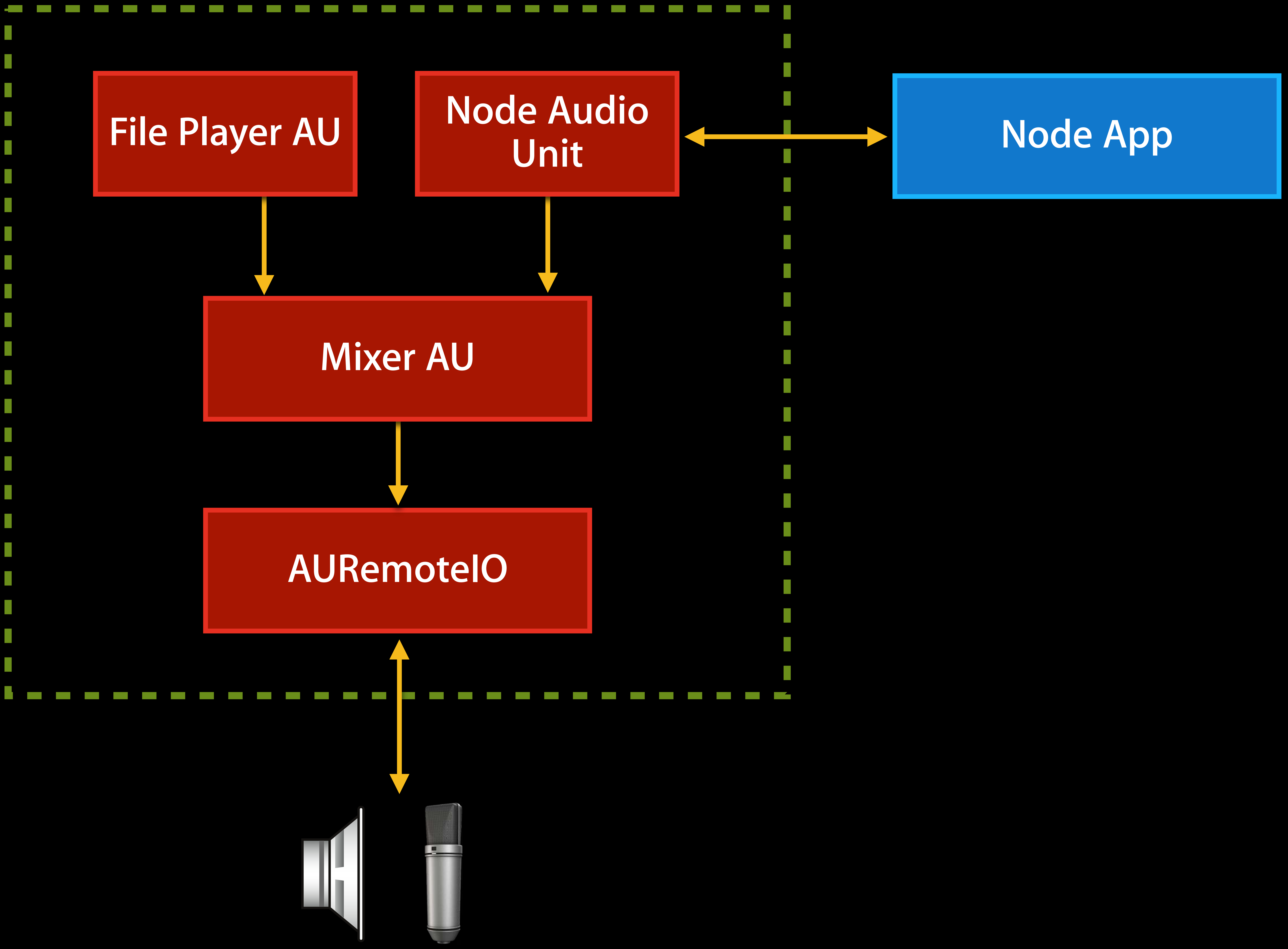
- Activate audio session
- Set stream formats
- Connect audio input
- Add disconnection listener
- Initialize

Host Rendering Node Audio



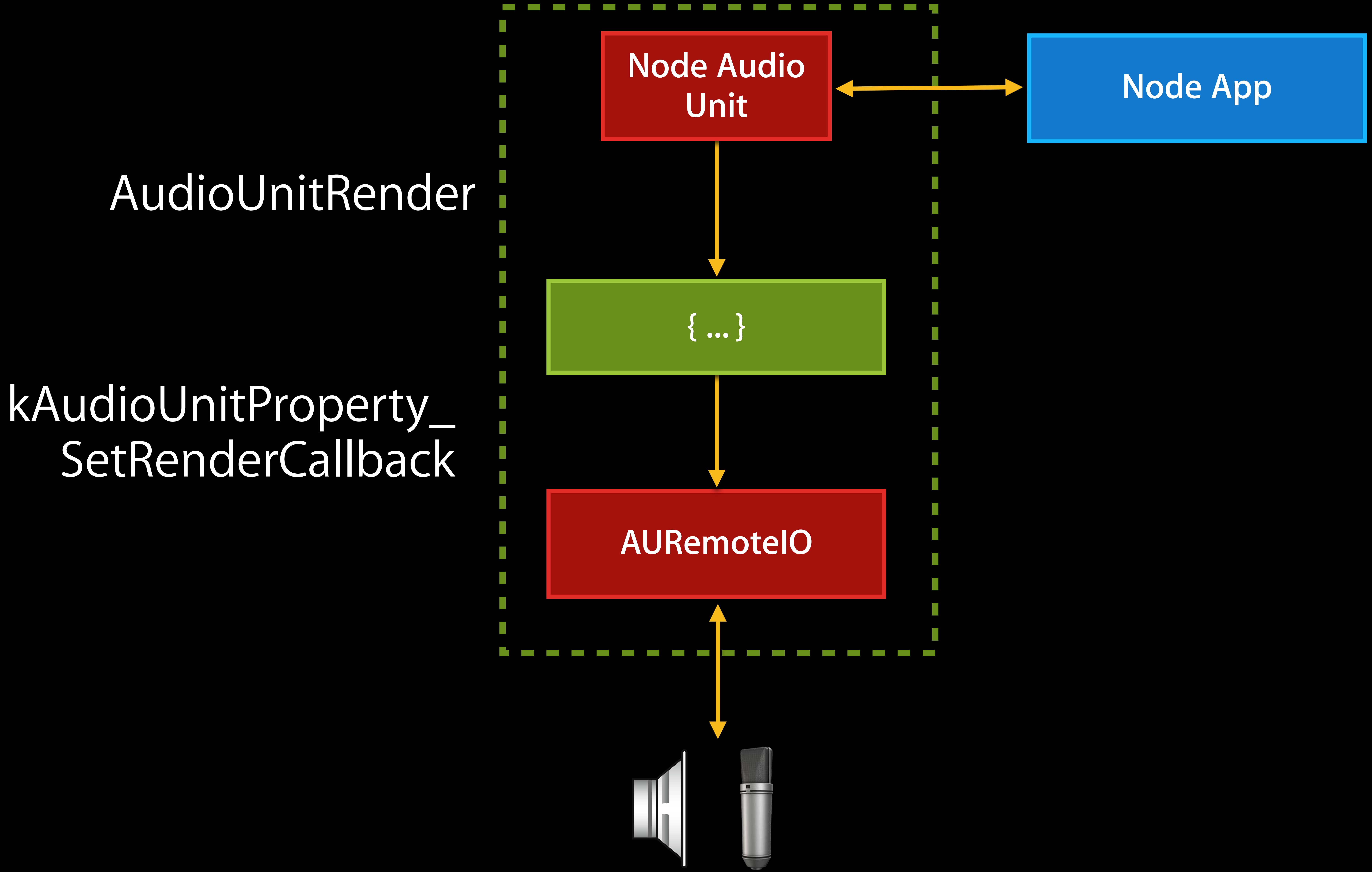
Host Rendering Node Audio

Using AUGraph



Host Rendering Node Audio

Using AudioUnits directly



Switching to a Node

- Do this after user opens the node
- Icon; tap to switch

```
void SwitchToNode(AudioUnit node)
{
    NSURL *url = NULL;
    UInt32 propertySize = sizeof(url);
    // property is CFURLRef but NSURL is toll-free-bridged.
    OSStatus err = AudioUnitGetProperty(peerAudioUnit,
  kAudioUnitProperty_PeerURL, kAudioUnitScope_Global, 0, &url,
  &propertySize);
    if (err) return;
    [[UIApplication sharedApplication] openUrl: url];
    [url release];
}
```

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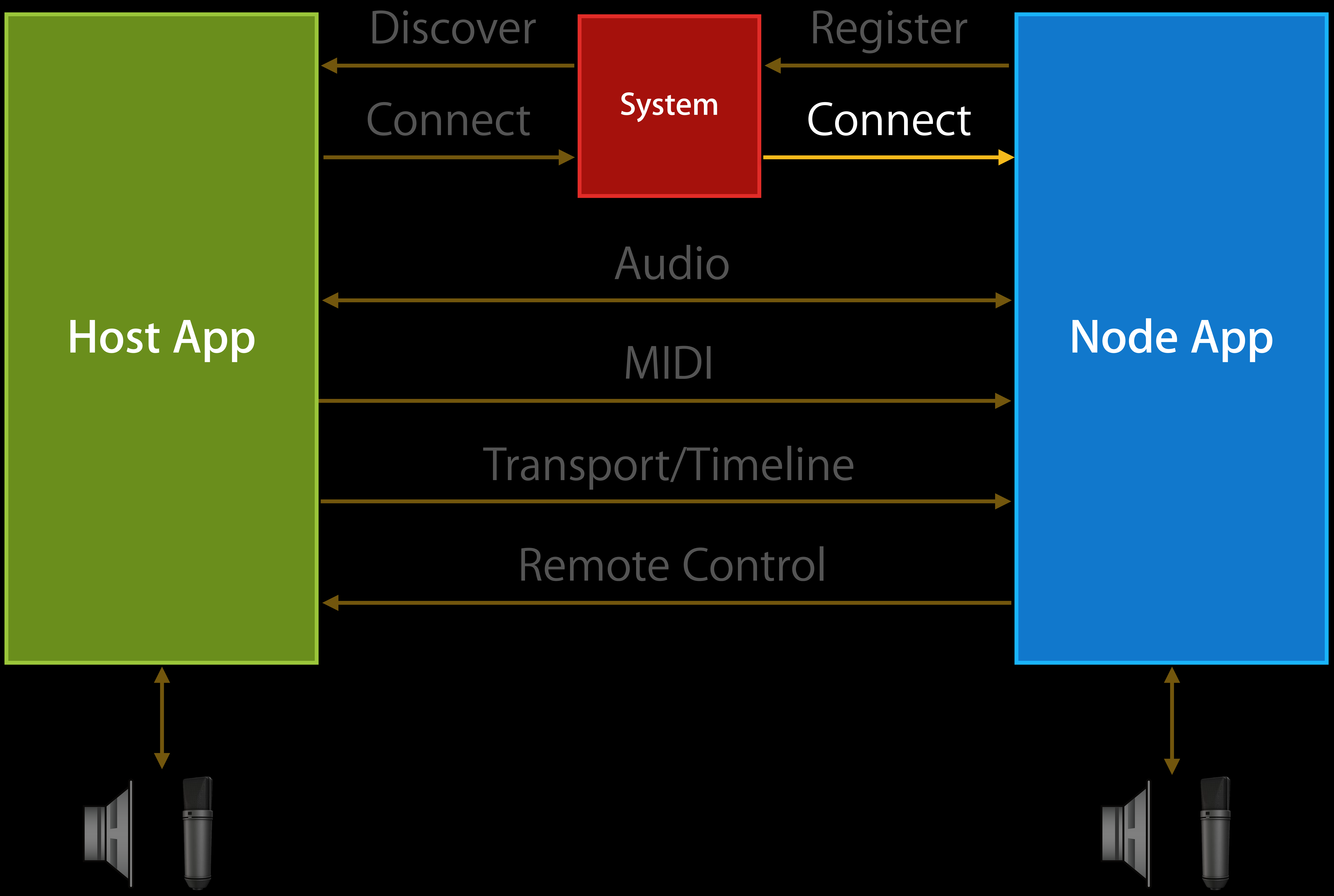
Being Connected (for Nodes)



Being Connected (for Nodes)

On launch

- Can be launched into the background
- Can’t start running from background
- Must publish I/O unit

```
UIApplicationState appstate =
    [UIApplication sharedApplication].applicationState;
_inForeground = (appstate != UIApplicationStateBackground);
```

Being Connected (for Nodes)

Handling connection

- kAudioUnitProperty_IsInterAppConnected
- When value becomes 1:
  - Output unit has been initialized
  - Set audio session active (if accessing mic)
  - Start running
  - Even if in the background
- AudioOutputUnitGetHostIcon

Being Connected (for Nodes)

Handling disconnection

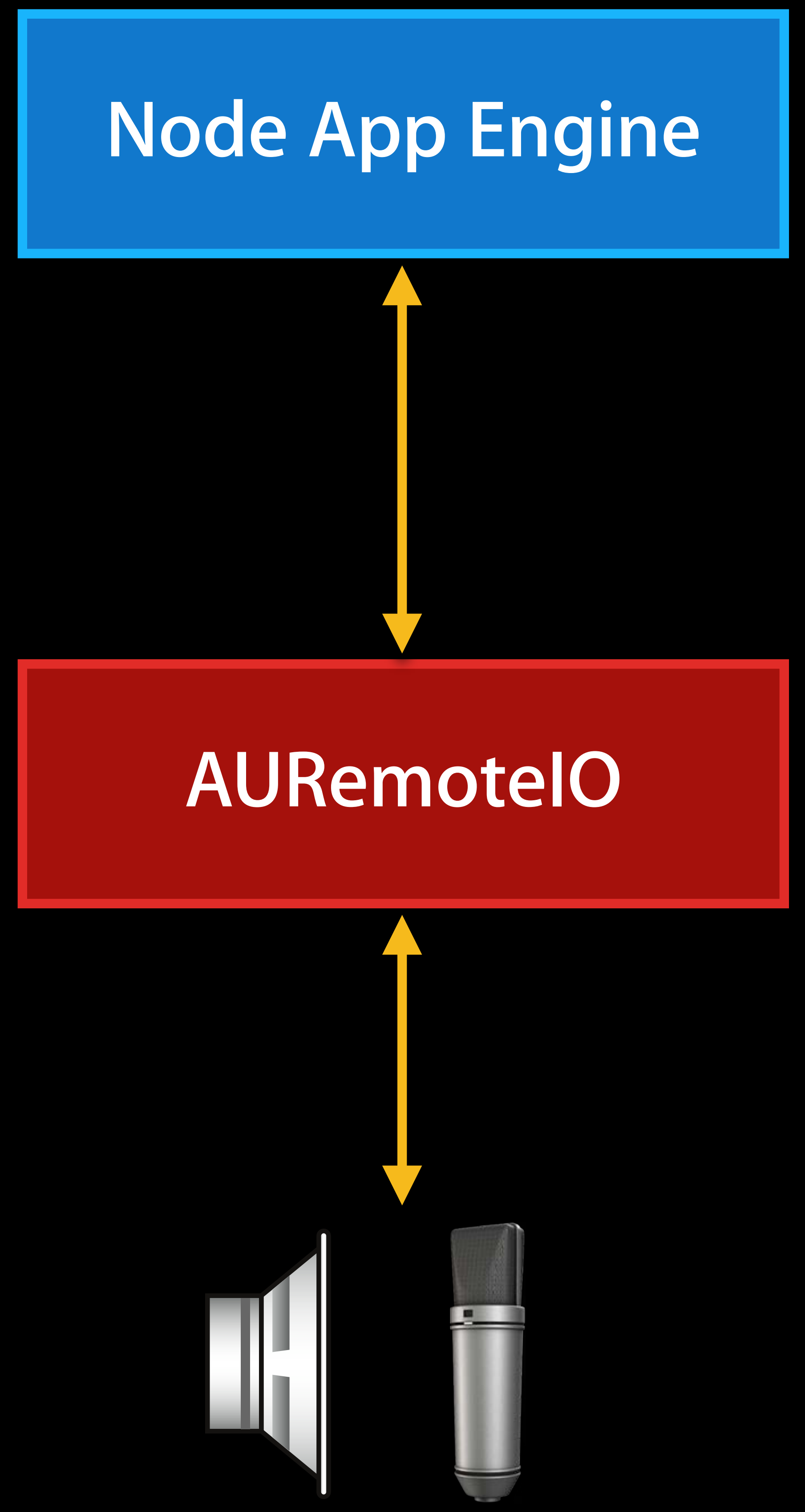
- When kAudioUnitProperty_IsInterAppConnected becomes 0:
    - Output unit has been uninitialized and stopped
    - Set audio session inactive (if using mic)
    - May set session active and resume running, but only if in the foreground

Running State (for Nodes)

- CanStart = Connected or InForeground
- Running = Connected or AppSpecificConditions

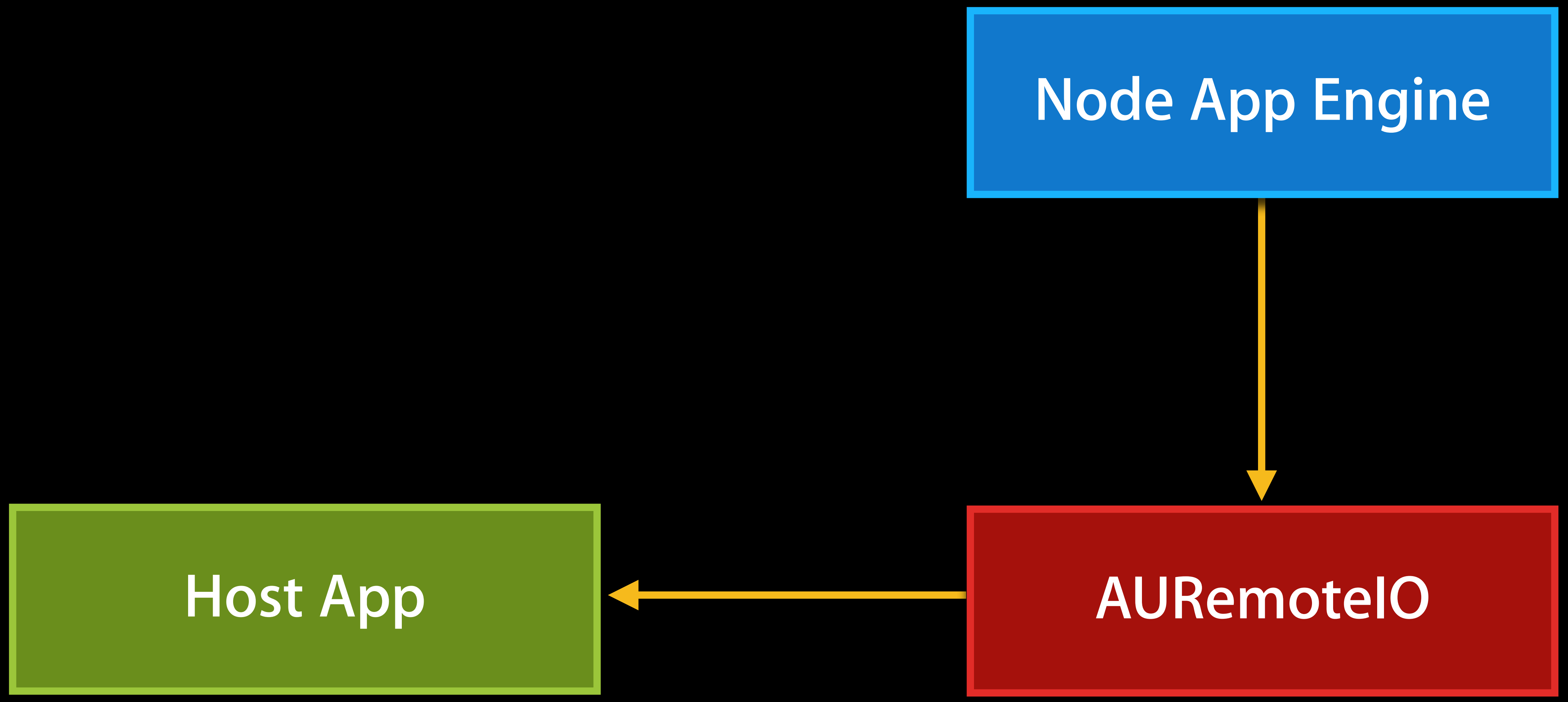
Node Rendering

Standalone



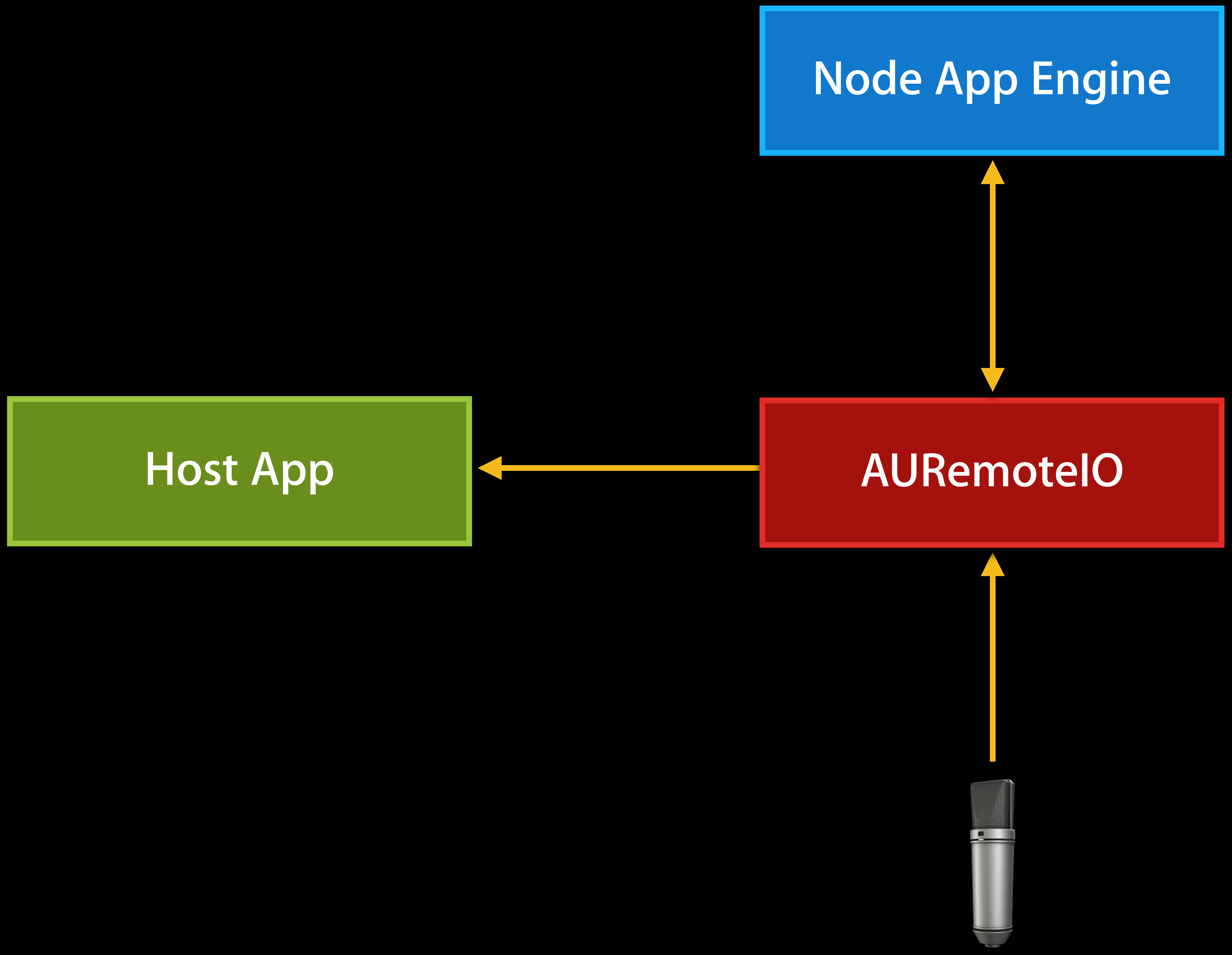
Node Rendering

Generator or instrument



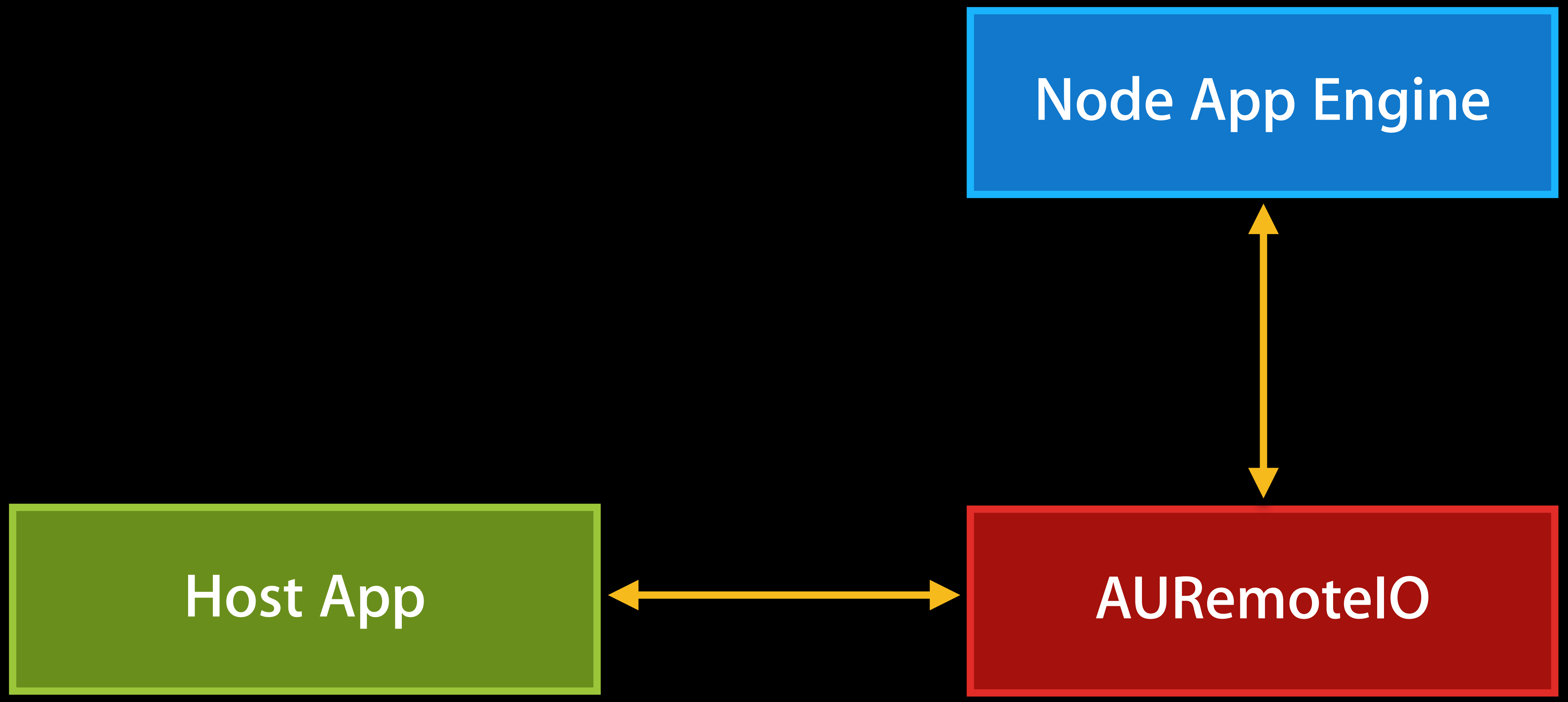
Node Rendering

Generator or instrument with audio input



Node Rendering

Effect



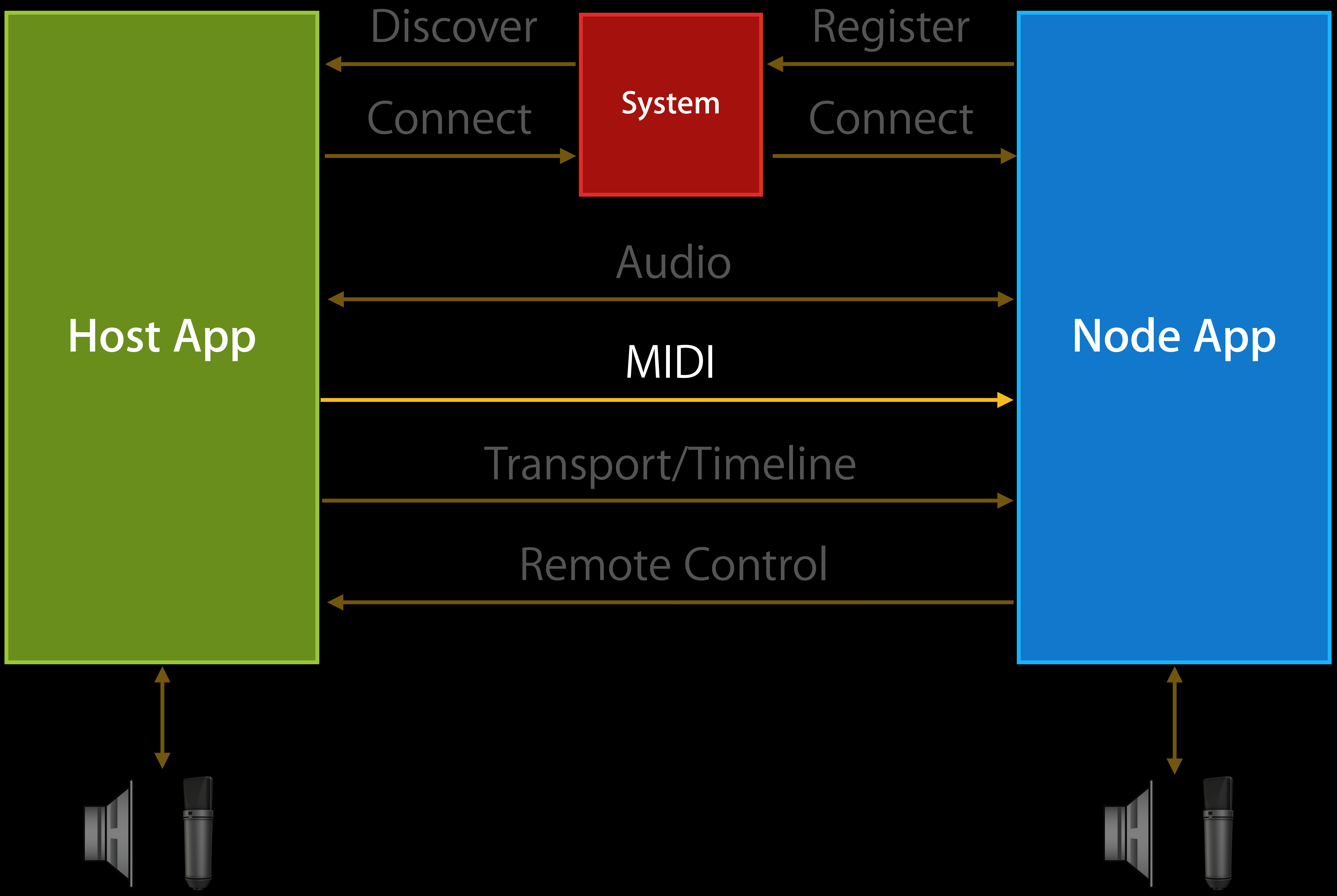
Switching from Node to Host

- Same as with host: Use `kAudioUnitProperty_PeerURL`

Stopping Audio Rendering (Host)

- AudioOutputUnitStop/AUGraphStop
- AudioUnitUninitialize
    - Release resources
    - Can re-initialize
- AudioComponentInstanceDispose
    - When completely finished
    - After node invalidated

MIDI



Host App
Discover
Connect
System
Register
Connect
Audio
MIDI
Transport/Timeline
Remote Control
Node App

MIDI

- For RemoteInstrument and RemoteMusicEffect nodes
    - When MIDI events tied to audio
    - Sample-accurate scheduling
    - Not for sync (clock/timecode)
- Complements CoreMIDI
    - USB/network
    - Apps that don’t support inter-app audio

Sending MIDI Events (Host)

Immediate, unscheduled

```
UInt32 offsetSampleFrames = 0;

const UInt8 kMIDINoteOn = 0x90;

const UInt8 kMiddleC = 60;

const UInt8 kVelocity = 64;

MusicDeviceMIDIEvent(myAudioUnit, kMIDINoteOn, kMiddleC, kVelocity,
  offsetSampleFrames);
```

Sending MIDI Events (Host)

Scheduled

```
double offsetSeconds = ...;
UInt32 offsetSampleFrames = offsetSeconds * sampleRate;
const UInt8 kMIDINoteOn = 0x90;
MusicDeviceMIDIEvent(myAudioUnit, kMIDINoteOn, 60 /* middle C */, 64,
  offsetSampleFrames);
AudioUnitRender(myAudioUnit, ...);
```

Sending MIDI Events (Host)

Scheduled, with AUGraph

```
AUGraphAddRenderNotify(myGraph, MyRenderNotify, self);

...

OSStatus MyRenderNotify(...
  const AudioTimeStamp *inTimeStamp
  ...
  UInt32 inNumberFrames ...)
{
     double offsetSeconds = ...;
     UInt32 offsetSampleFrames = offsetSeconds * sampleRate;
     const UInt8 kMIDINoteOn = 0x90;
     MusicDeviceMIDIEvent(myAudioUnit, kMIDINoteOn, 60 /* middle C */, 64,
       offsetSampleFrames);
     ...
}
```

Receiving MIDI Events (Node)

MIDI Callbacks

```
typedef struct {
   void *userData;
   // see MusicDeviceMIDIEvent, MusicDeviceSysEx
   void (*MIDIEventProc)(void *userData, UInt32 inStatus,
              UInt32 inData1, UInt32 inData2, UInt32 inOffsetSampleFrame);
   void (*MIDISysExProc)(void *userData, const UInt8* inData,
              UInt32 inLength);
} AudioOutputUnitMIDICallbacks;
```

Receiving MIDI Events (Node)

```
void MyMIDIEventProc(void *userData, UInt32 inStatus,
   UInt32 inData1, UInt32 inData2, UInt32 inOffsetSampleFrame)
{
   MyEngine *engine = (MyEngine *)userData;
   ...
}

void InstallMIDICallbacks(MyEngine *engine)
{
   AudioOutputUnitMIDICallbacks callbacks;
   callbacks.userData = engine;
   callbacks.MIDIEventProc = MyMIDIEventProc;
   callbacks.MIDISysExProc = NULL;
   AudioUnitSetProperty(myOutputUnit, kAudioOutputUnitProperty_MIDICallbacks,
     kAudioUnitScope_Global, 0,
     &callbacks, sizeof(callbacks));
}
```

Receiving MIDI Events (Node)

```
void MyMIDIEventProc(void *userData, UInt32 inStatus,
   UInt32 inData1, UInt32 inData2, UInt32 inOffsetSampleFrame)
{
   MyEngine *engine = (MyEngine *)userData;
   ...
}
```

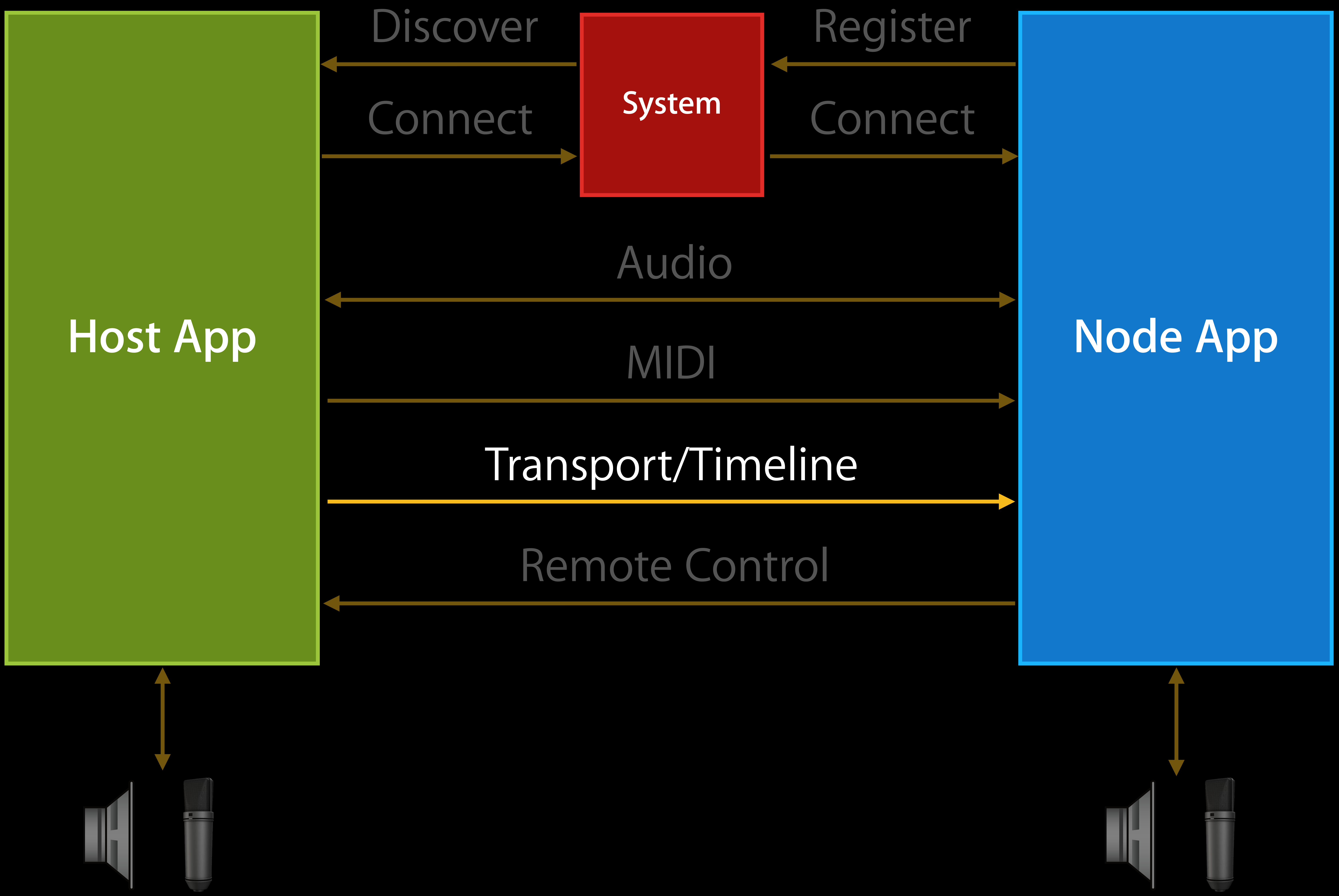
```
void InstallMIDICallbacks(MyEngine *engine)
{
   AudioOutputUnitMIDICallbacks callbacks;
   callbacks.userData = engine;
   callbacks.MIDIEventProc = MyMIDIEventProc;
   callbacks.MIDISysExProc = NULL;
   AudioUnitSetProperty(myOutputUnit, kAudioOutputUnitProperty_MIDICallbacks,
     kAudioUnitScope_Global, 0,
     &callbacks, sizeof(callbacks));
}
```

Receiving MIDI Events (Node)

```
void MyMIDIEventProc(void *userData, UInt32 inStatus,
   UInt32 inData1, UInt32 inData2, UInt32 inOffsetSampleFrame)
{
  MyEngine *engine = (MyEngine *)userData;
  ...
}
```

```
void InstallMIDICallbacks(MyEngine *engine)
{
  AudioOutputUnitMIDICallbacks callbacks;
  callbacks.userData = engine;
  callbacks.MIDIEventProc = MyMIDIEventProc;
  callbacks.MIDISysExProc = NULL;
  AudioUnitSetProperty(myOutputUnit, kAudioOutputUnitProperty_MIDICallbacks,
    kAudioUnitScope_Global, 0,
    &callbacks, sizeof(callbacks));
}
```

Transport and Timeline Information



Transport and Timeline Information

- Host is master; node can synchronize
- Musical position
- Transport state
- Called at render time

Transport and Timeline Information

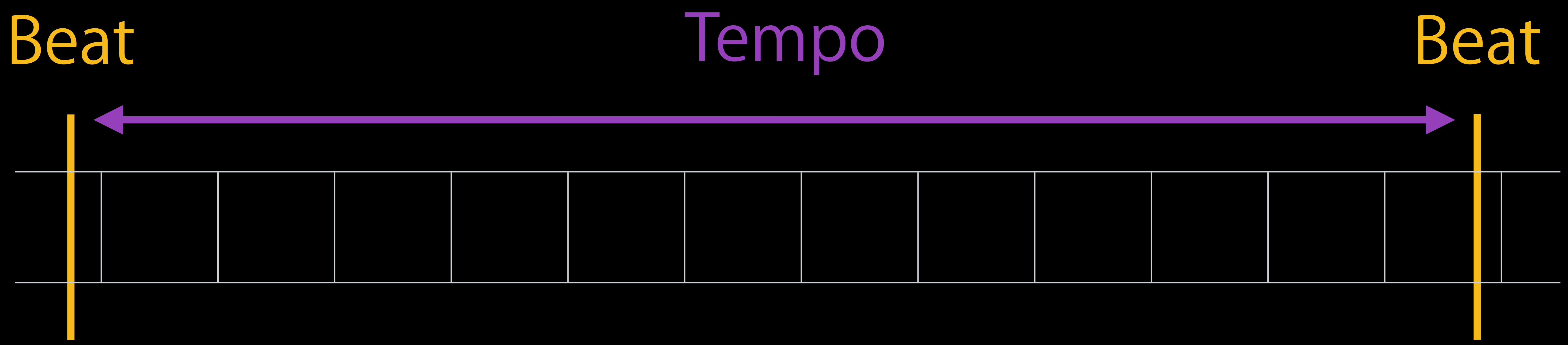
HostCallbackInfo

```
typedef struct HostCallbackInfo {
    void *                                  hostUserData;
    HostCallback_GetBeatAndTempo            beatAndTempoProc;
    HostCallback_GetMusicalTimeLocation     musicalTimeLocationProc;
    HostCallback_GetTransportState          transportStateProc;
    HostCallback_GetTransportState2         transportStateProc2;
} HostCallbackInfo;
```

Providing Host Callbacks

Beat and tempo

```
OSStatus MyBeatAndTempo(...)
{
   *outCurrentBeat = ...;  // position in track (float)
   *outCurrentTempo = ...; // beats per minute
   return noErr;
}
```



Providing Host Callbacks

Musical time location

```
OSStatus MyMusicalTimeLocation(...)
{
   *outDeltaSampleOffsetToNextBeat = ...;
   *outTimeSigNumerator = ...;
   *outTimeSigDenominator = ...;
   *outCurrentMeasureDownbeat = ...;
   return noErr;
}
```

Providing Host Callbacks

Transport state

```
OSStatus MyGetTransportState(...)
{
   *outIsPlaying = ...;
   *outIsRecording = ...;
   *outTransportStateChanged = ...;
   *outCurrentSampleInTimeline = ...;
   *outIsCycling = ...;
   *outCycleStartBeat = ...;
   *outCycleEndBeat = ...;
   return noErr;
}
```

Installing Host Callbacks

```
void InstallHostCallbacks(MyEngine *engine, AudioUnit myAudioUnit)
{
   HostCallbackInfo hci;

   hci.hostUserData = engine;
   hci.beatAndTempoProc = MyBeatAndTempo;
   hci.musicalTimeLocationProc = MyMusicalTimeLocation;
   hci.transportStateProc = NULL;
   hci.transportStateProc2 = MyGetTransportState;

   AudioUnitSetProperty(myAudioUnit, kAudioUnitProperty_kHostCallbacks,
     kAudioUnitScope_Global, 0,
     &hci, sizeof(hci));
}
```

Using Host Callbacks (Node)

- Get kAudioUnitProperty_HostCallbacks at connection time

```
HostCallbackInfo myHostCallbacks;

UInt32 propertySize = sizeof(myHostCallbacks);

AudioUnitGetProperty(myIOUnit, kAudioUnitProperty_kHostCallbacks,
  kAudioUnitScope_Global, 0,
  &myHostCallbacks, &propertySize);
```

- Call the desired host callback(s) at render time
- Caution: Thread-safety

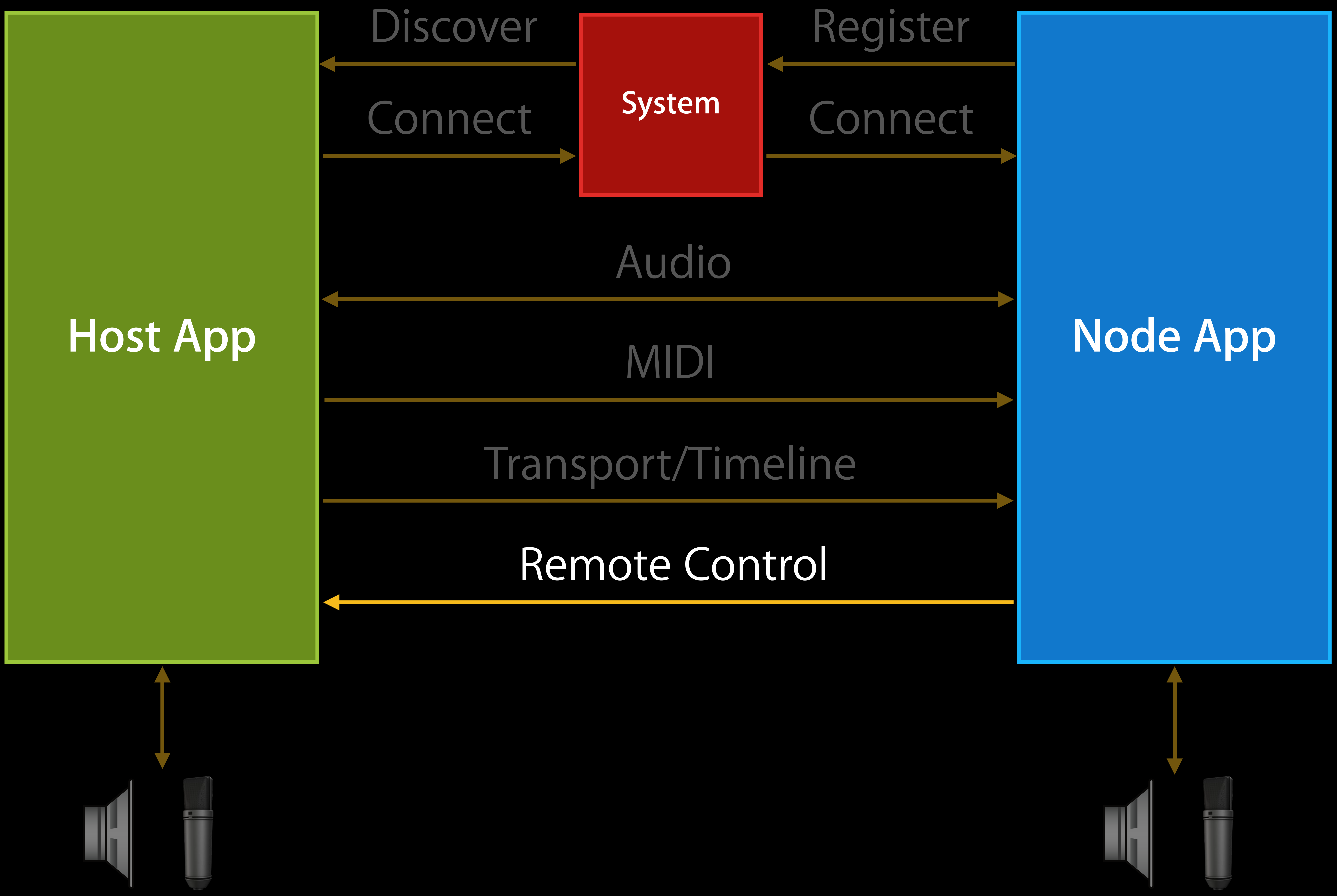
Using Host Callbacks (Node)

Observing transport state changes

- Transport state listener
- Called on non-render thread

```
AudioUnitAddPropertyListener(myIOUnit,
  kAudioOutputUnitProperty_HostTransportState,
  MyTransportStateListener, self);
```

Remote Control



Audio Unit Remote Control Events

- Distinct from UIKit remote control events
- Node can control host's transport

```
enum {
    kAudioUnitRemoteControlEvent_TogglePlayPause = 1,
    kAudioUnitRemoteControlEvent_ToggleRecord    = 2,
    kAudioUnitRemoteControlEvent_Rewind          = 3
};
typedef UInt32 AudioUnitRemoteControlEvent;
```

- Node: Use the recommended transport controls in the sample app

Audio Unit Remote Control Events

From node

- Query whether host supports them:

```
UInt32 eventsSupported = 0, propertySize = sizeof(eventsSupported);
AudioUnitGetProperty(myIOUnit,
  kAudioOutputUnitProperty_HostReceivesRemoteControlEvents,
  kAudioUnitScope_Global, 0,
  &eventsSupported, &propertySize);
```

- Send an event:

```
AudioUnitRemoteControlEvent theControl =
  kAudioUnitRemoteControlEvent_ToggleRecord;
AudioUnitSetProperty(myIOUnit,
  kAudioOutputUnitProperty_RemoteControlToHost,
  kAudioUnitScope_Global, 0,
  &theControl, sizeof(theControl));
```

Audio Unit Remote Control Events

In host

- Set kAudioUnitProperty_RemoteControlEventListener

```
AudioUnitRemoteControlEventListener listenerBlock =
  ^(AudioUnitRemoteControlEvent event) {
    [self handleRemoteEvent: event];
  };

AudioUnitSetProperty(myAudioUnit,
  kAudioOutputUnitProperty_RemoteControlEventListener,
  kAudioUnitScope_Global, 0,
  &listenerBlock, sizeof(listenerBlock));
```

Demo

Inter-app host, instrument and effect, with remote control

Harry Tormey

Audio Session Interruptions

- The usual rules apply
  - Your remote I/O has already been stopped underneath you
- In hosts, system has uninitialized your node audio units

Handling Media Services Reset

- AVAudioSessionMediaServicesWereResetNotification
- All inter-app audio connections are broken (component instances invalidated)
- Host: Dispose node AudioUnit and AURemoteIO
- Node: Dispose AURemoteIO
- Proceed as if app has been launched

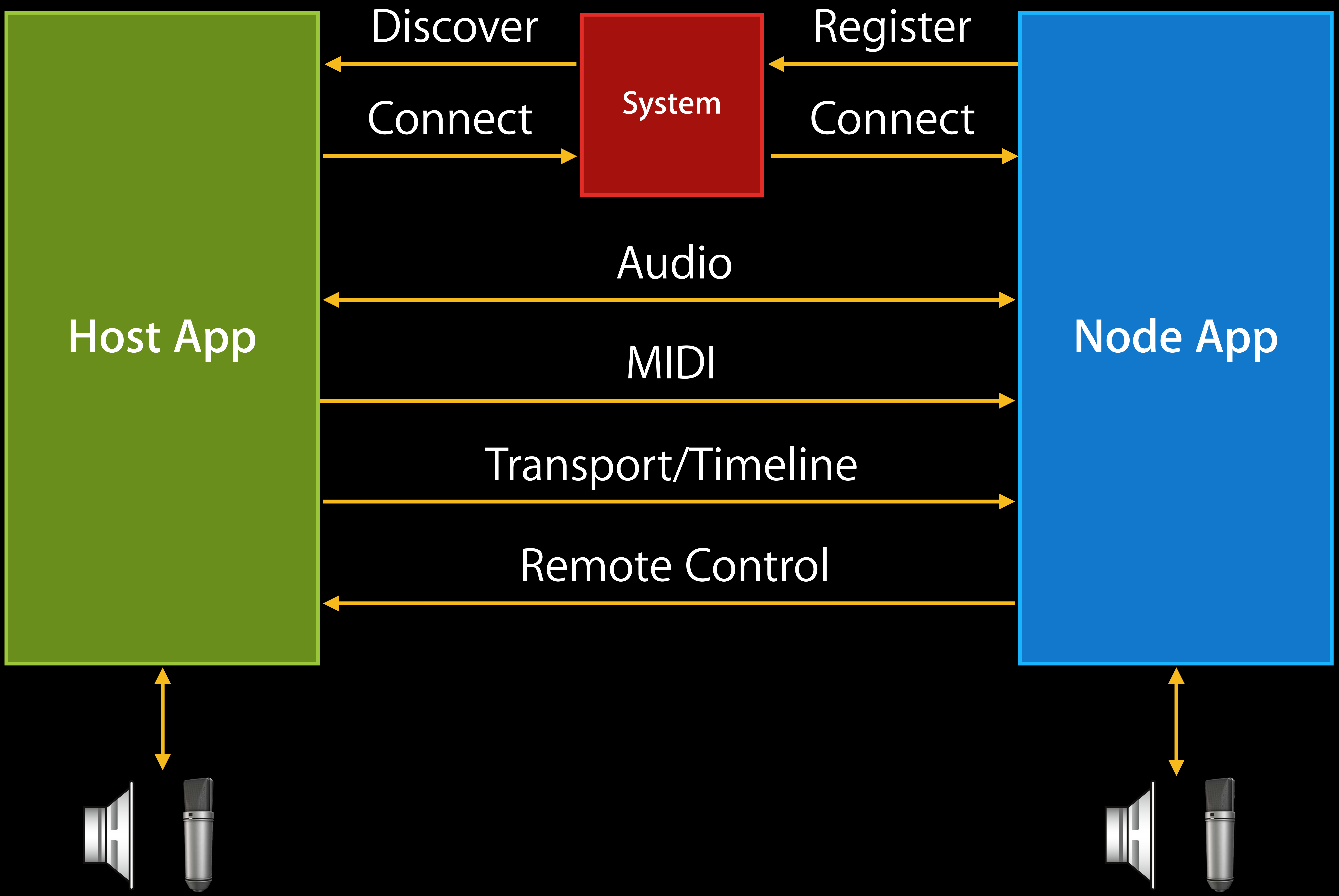
Odds and Ends

- Multiple hosts?
  - If all mixable, yes
- Multiple nodes?
  - Yes

Tips

- Debug node registration
    - Watch console log
- Error -12985
    - “Operation denied”
    - Can’t start playing from the background

Review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Conclusion

- Existing apps can be converted to nodes fairly simply
- Creating a host is a bit more work, but use AudioUnit APIs for power and flexibility
- Use sample code from WWDC library
- Make great music apps!

Apple Evangelists
Contact information

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Documentation
AV Foundation Programming Guide
http://developer.apple.com/library/ios/#documentation/AudioVideo/Conceptual/AVFoundationPG/

Apple Developer Forums
http://devforums.apple.com

Related Sessions

Moving to AV Kit and AV Foundation	Pacific Heights Tuesday 4:30PM
Preparing and Presenting Media for Accessibility	Nob Hill Wednesday 10:15AM
What's New in Camera Capture	Nob Hill Wednesday 11:30AM
Advanced Editing with AV Foundation	Marina Thursday 9:00AM

Labs

Audio Lab	Media Lab B Tuesday 2:00PM
Audio Lab	Media Lab B Wednesday 9:00AM

WWDC2013