C++ Coroutines and Qt

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Blocking – Root of All Evil

```
QString RemotePlayer::getTitle() {
    QDBusInterface player{
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Let’s Fix It!

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    const auto title = co_await remotePlayer.getTitle();
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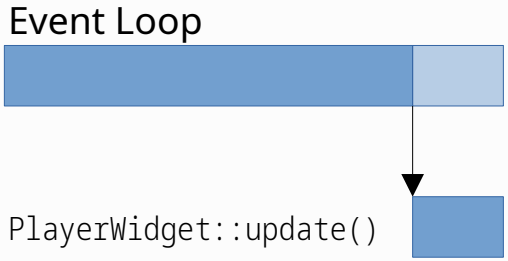
Execution Flow with Coroutine

Event Loop

Execution Flow with Coroutine



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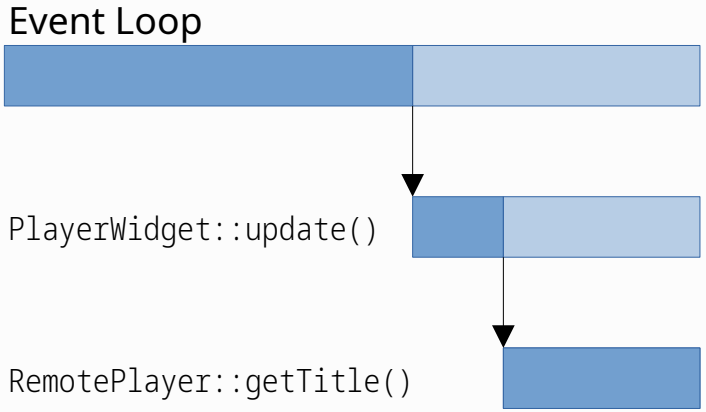

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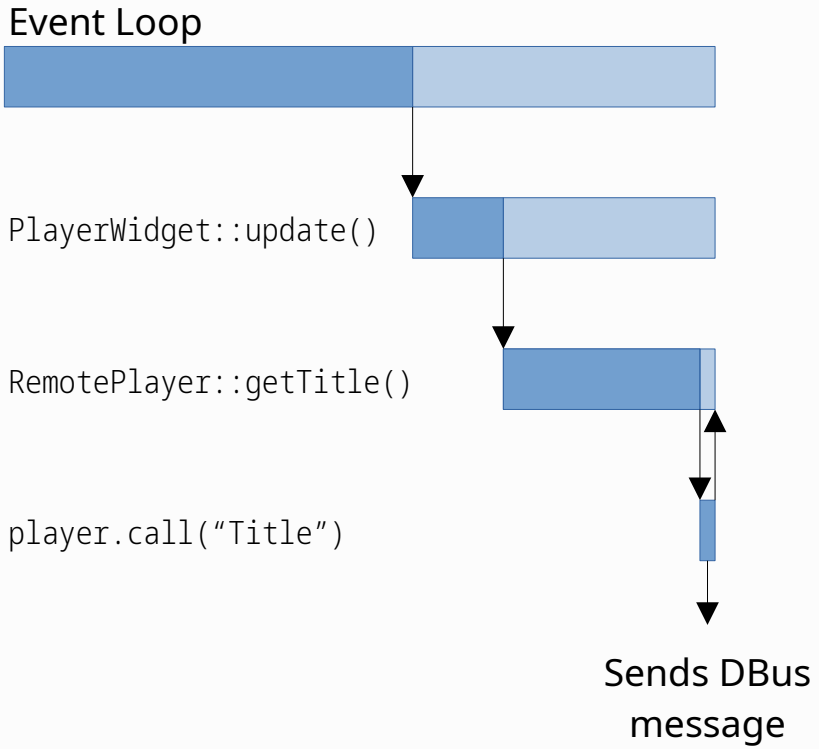

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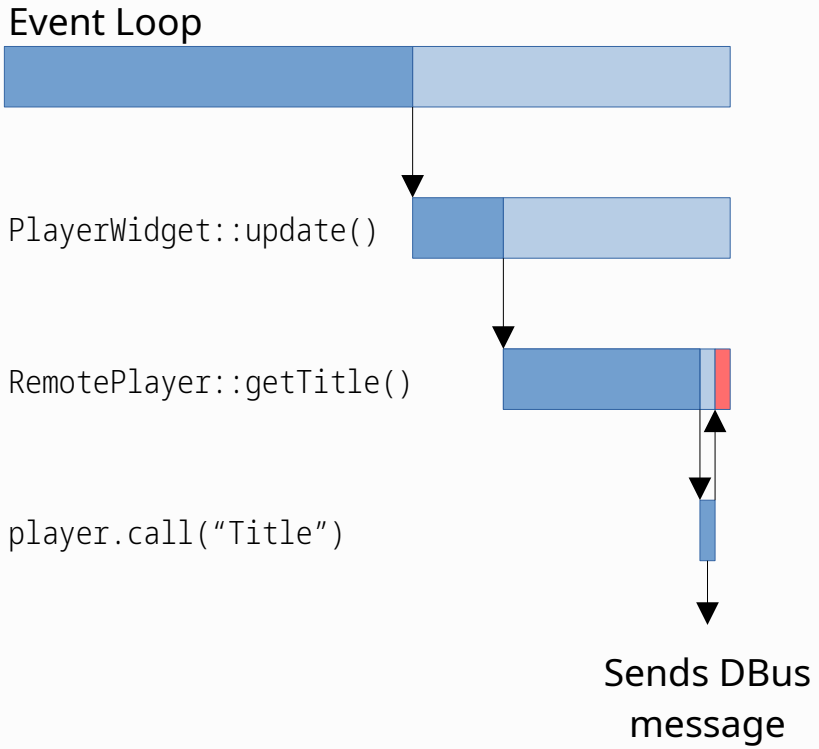

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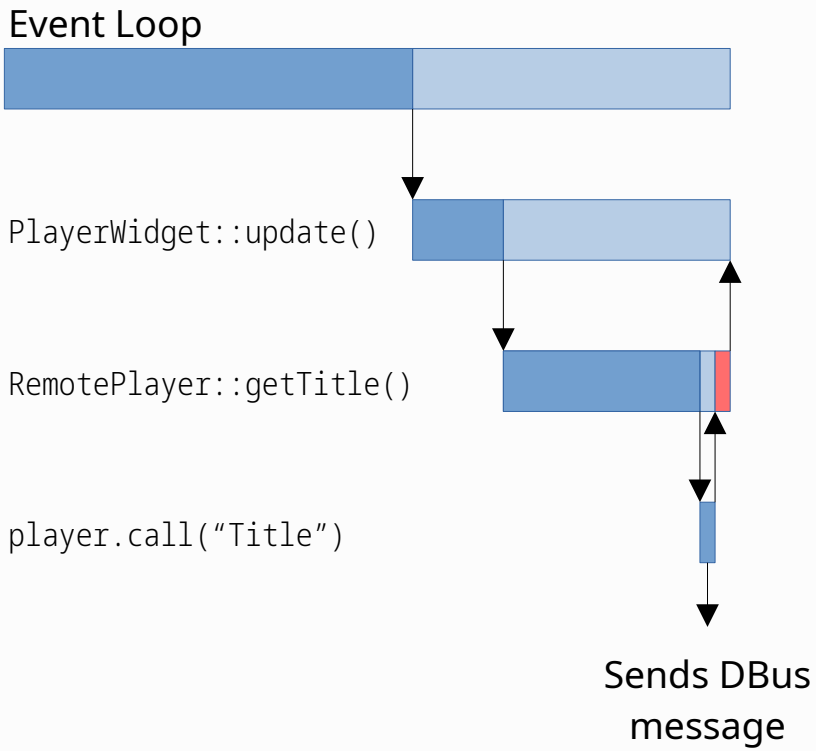

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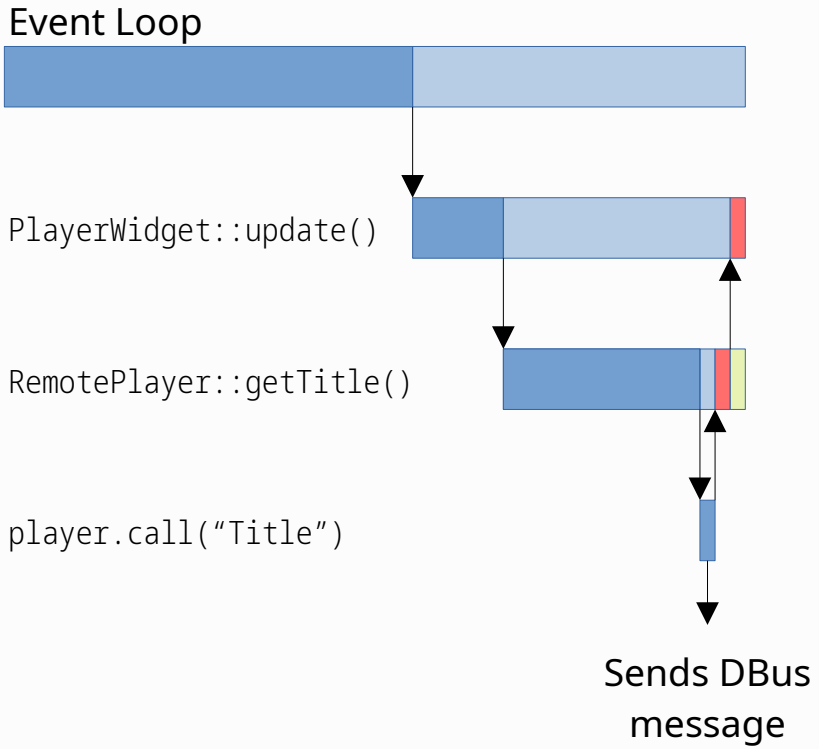

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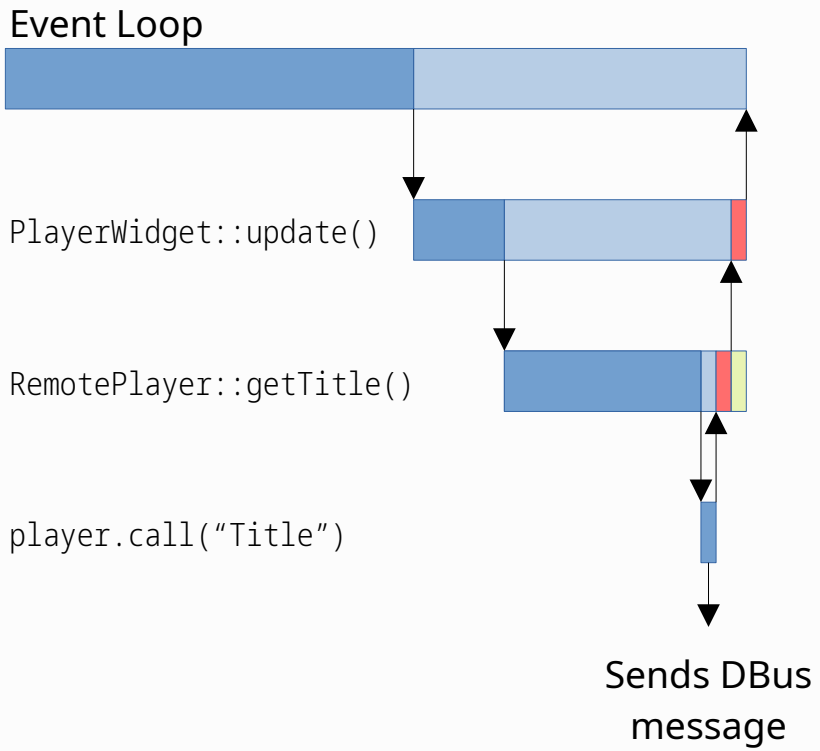

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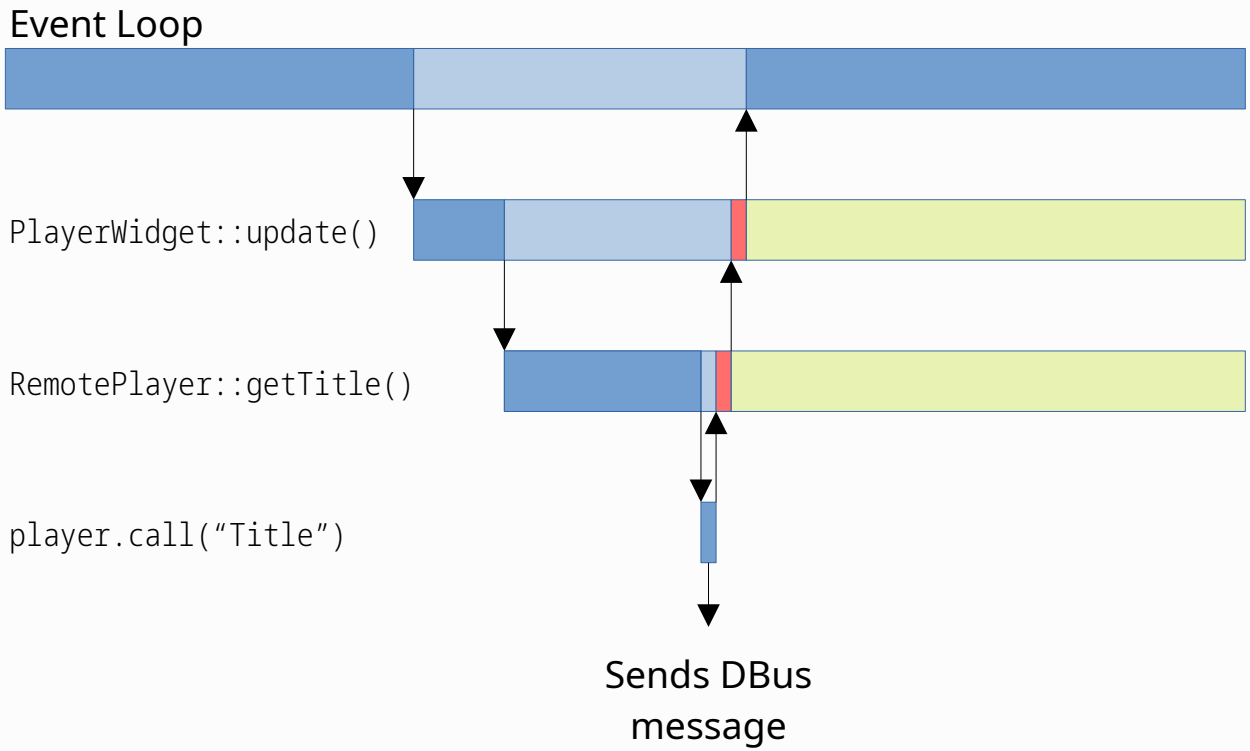

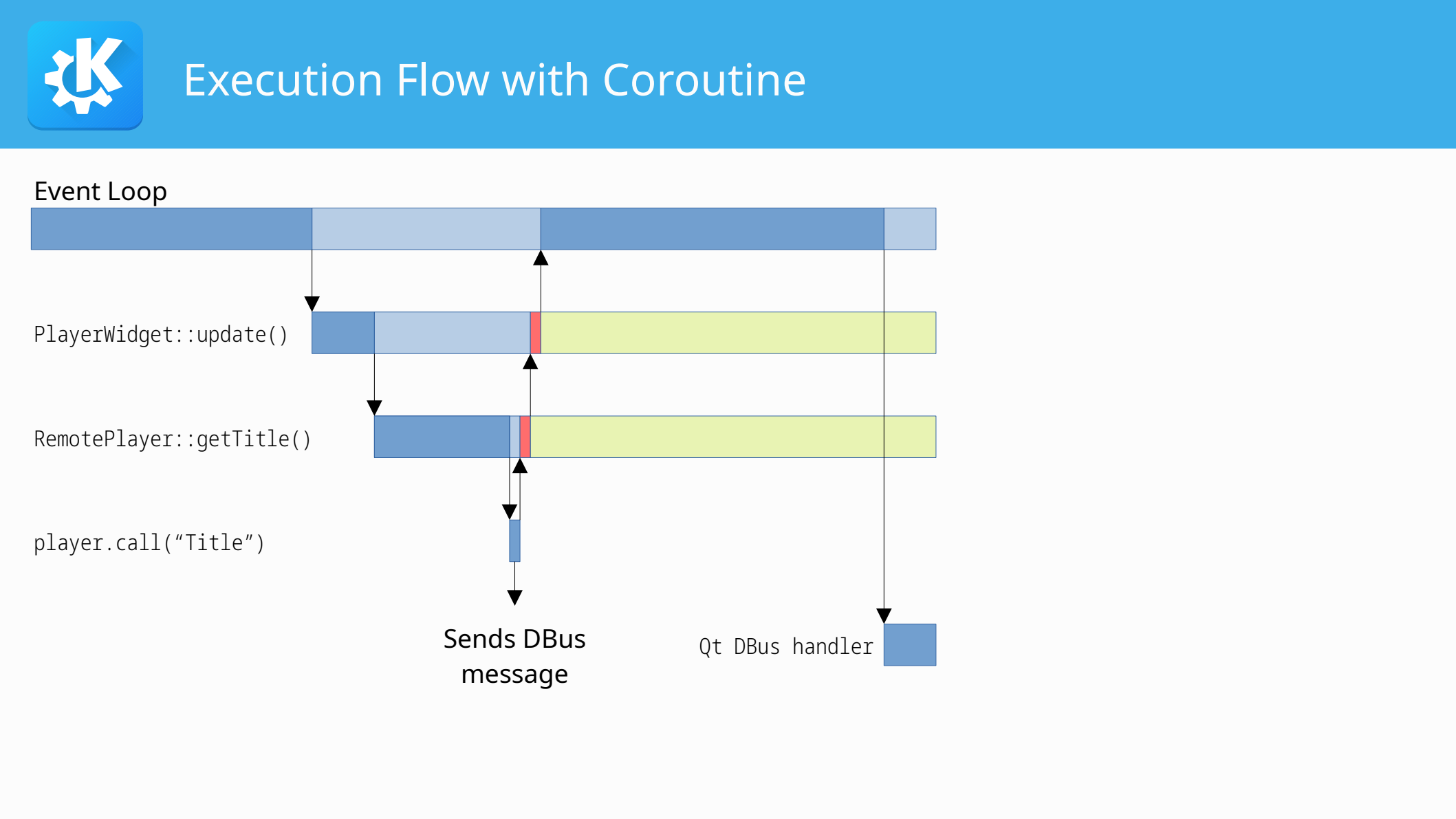
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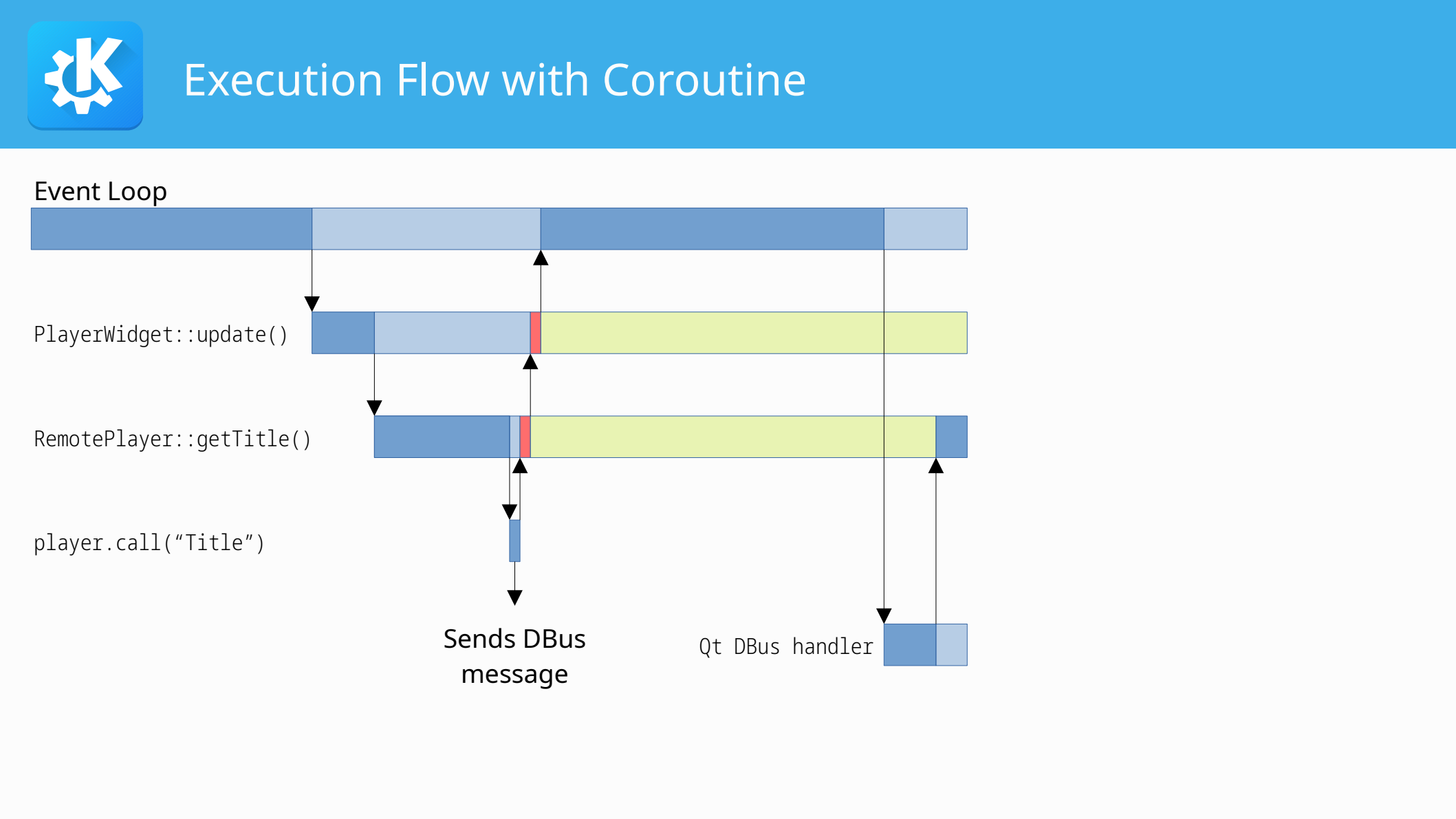
PlayerWidget::update()
RemotePlayer::getTitle()
player.call("Title")
Sends DBus message
Qt DBus handler



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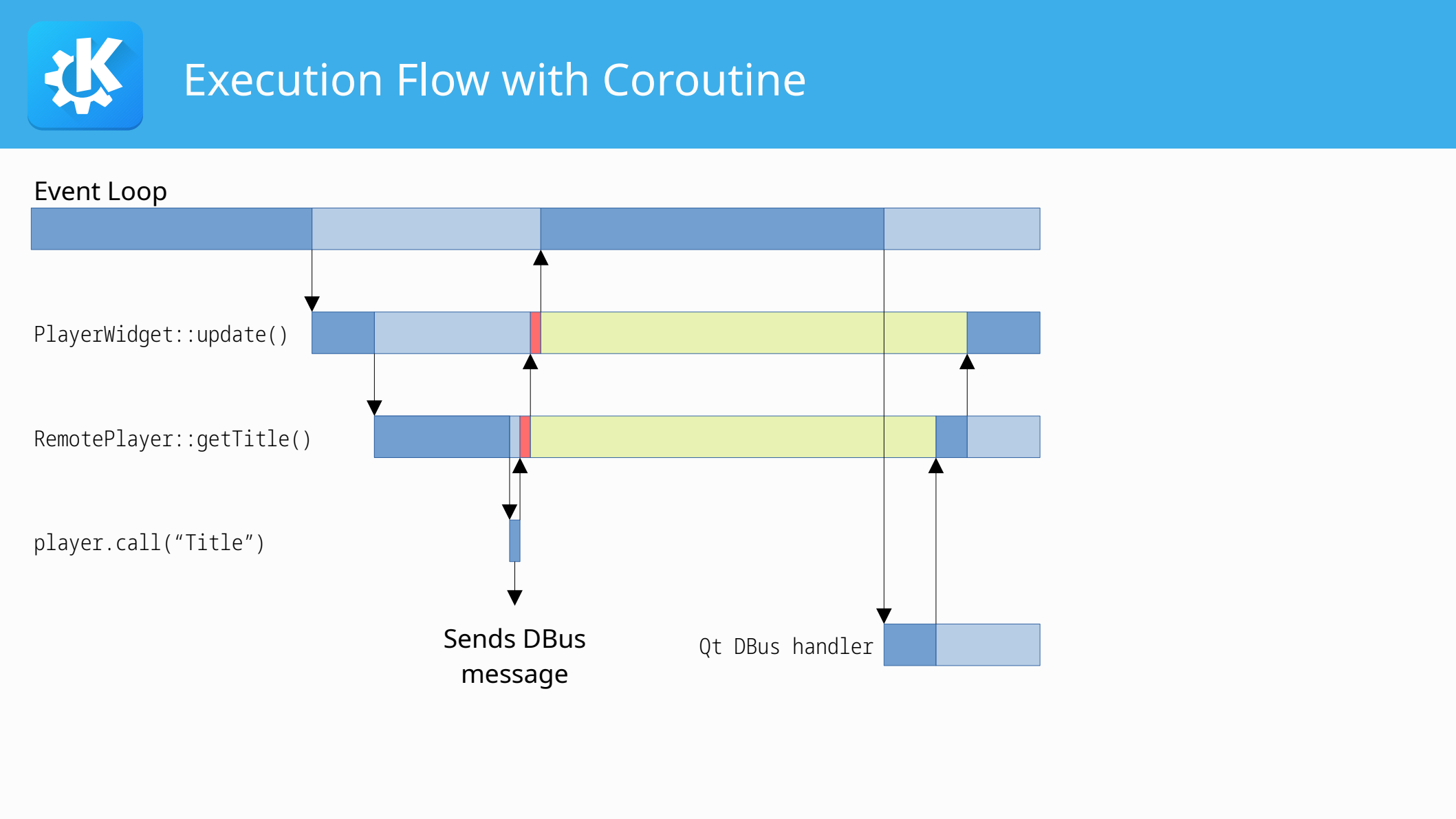
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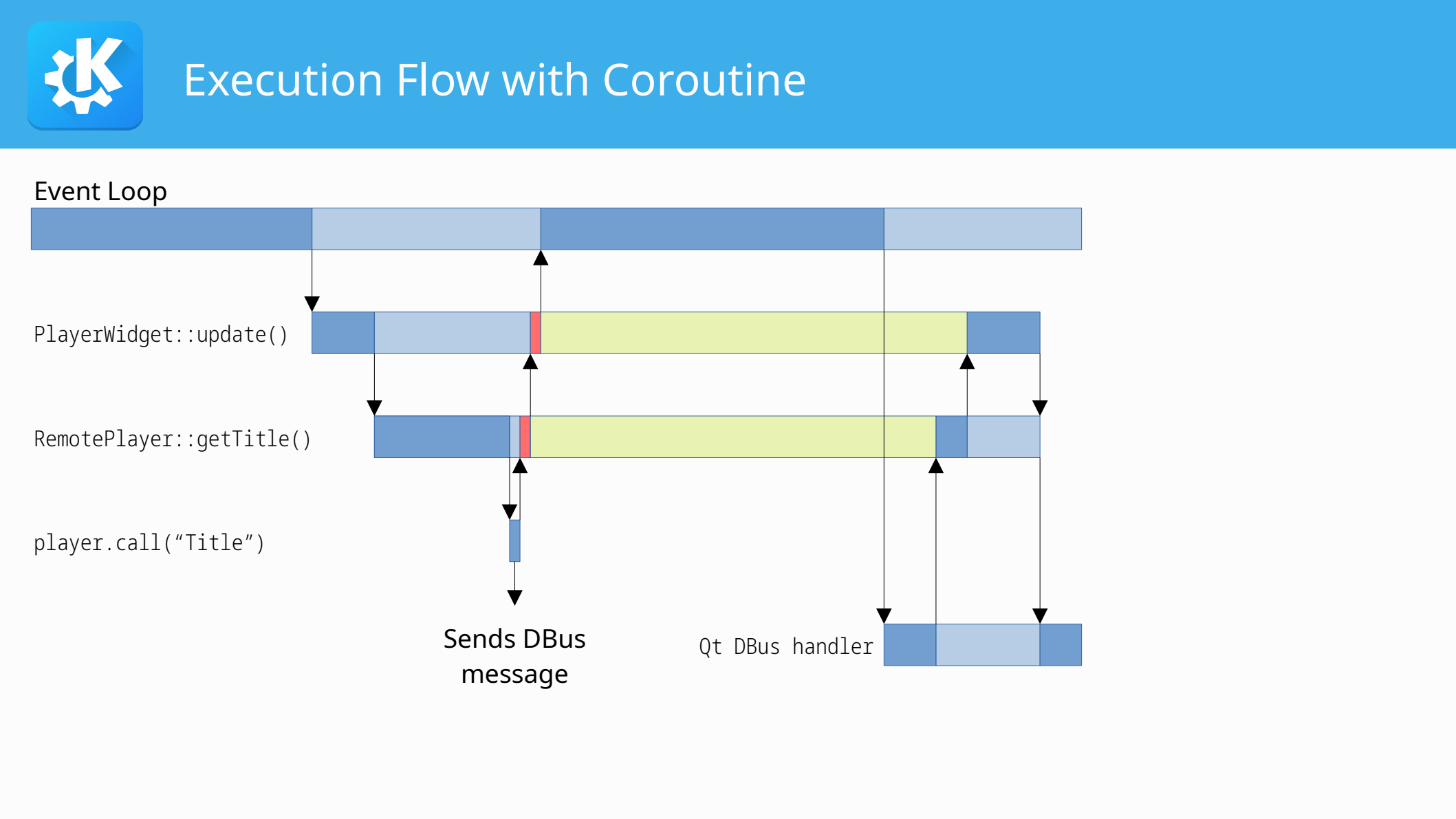
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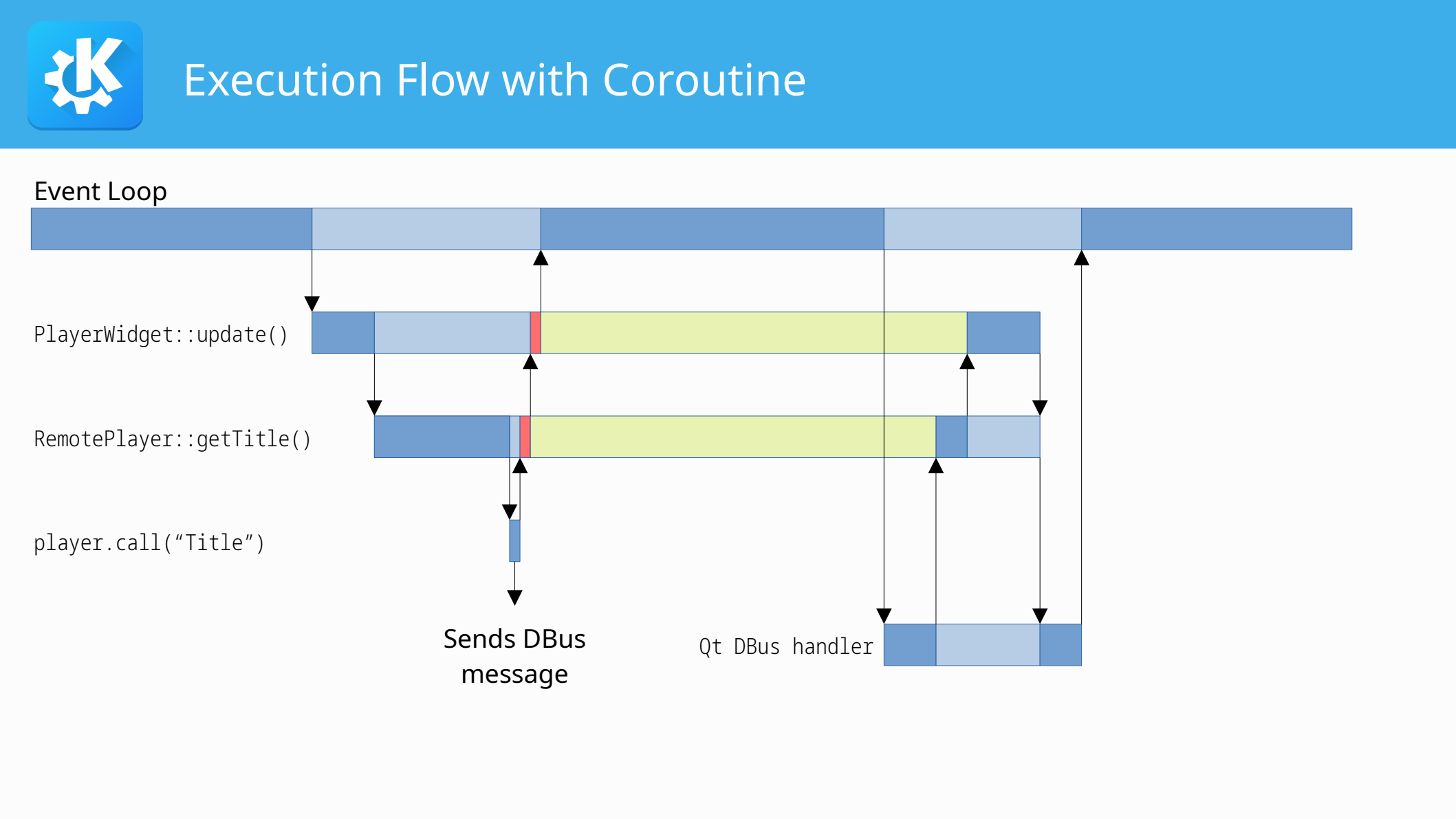
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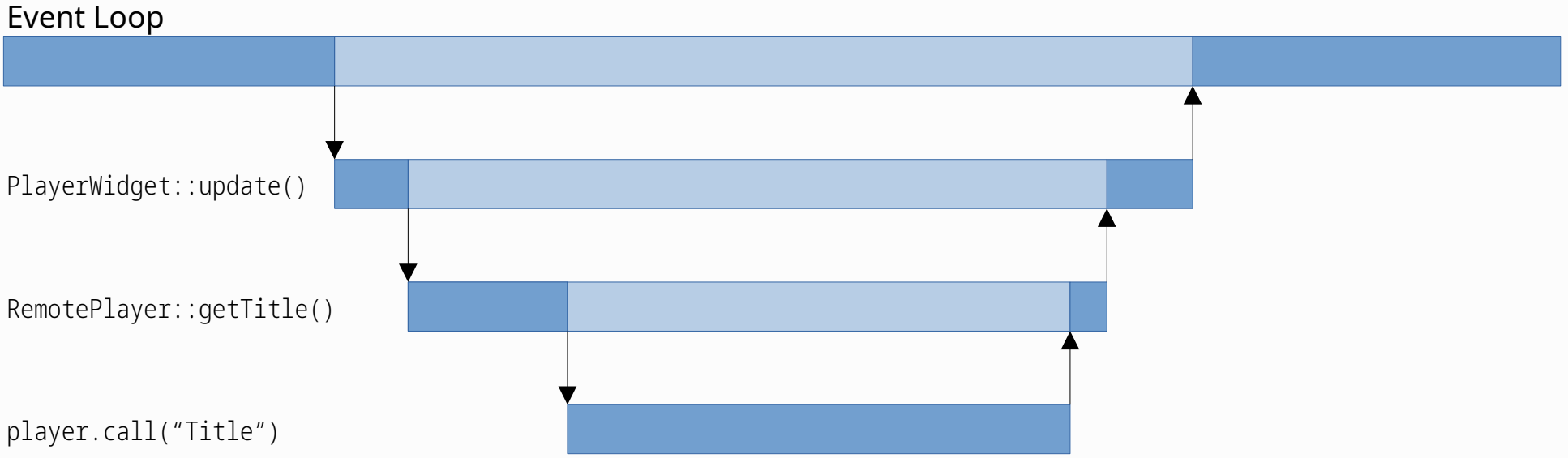
Execution Flow with Regular Functions



Coroutines in General

- Well-established concept in many programming languages
- Coroutine is a function whose execution can be suspended and resumed again at later point in time.
- When a coroutine is suspended, execution returns to its caller.
- When a coroutine is resumed, it’s as if it were called from the function that resumed it.
- Allows writing asynchronous code in a synchronous manner.
- Does not necessarily improve performance.

Coroutines in C++

1) Introduced in C++20
2) Compiler support
   - GCC 10 (`-fcoroutines`), `<coroutine>`
   - Clang 5 (`-fcoroutines-ts -stdlib=libc++`), `<experimental/coroutine>`
   - MSVC 14.28 (VS 2019 16.8) (`/await`), `<coroutine>`
3) Core language extension
4) Limited support in standard library (only bare minimum to support compilers and coroutine library writers)

Coroutines in C++ (cont.)

Three new keywords:

- `co_await` – suspends the coroutine while awating completion
- `co_return` – returns a result from a coroutine (like return)
- `co_yield` – provides intermediate result (useful for generators)

Standard Library

- `coroutine_handle` – handle, allows resuming the coroutine
- `suspend_never` – indicates that the coroutine should never suspend
- `suspend_always` – indicates that the coroutine should always suspend

How To Make a Coroutine

1) Must contain `co_await` or `co_yield` keyword
2) Must have a return type that
   - has a `promise_type` typedef specifying the *Promise* type
   - usually templated – e.g. `Task<T>` - where `T` is the type of the actual coroutine result
   - the STL does not provide any such return type!
   - The return type is an interface for the caller, the *Promise* type is an interface for the coroutine
3) Must use `co_return` instead of `return`

But Wait!

```
QCoro::Task<QString> PlayerController::getTitle() {
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    const QString title = co_await QDBusReply<QString>{player.call("Title")};
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}
```

Coroutines and Qt

- `co_await` expects an argument that either
  - is *Awaitable* or,
  - there's a compatible `promise_type::await_transform(T)` overload
    - `await_transform` returns a wrapper for `T` that is *Awaitable*

QCoro Library

- A small library that provides
  - a custom *Awaitable* return type for coroutines
  - `await_transform()` implementation for many Qt types
  - thin *Awaitable* wrappers for async operations on various Qt types

QCoro Library

Certain types only have one operation that makes sense to be co_awaited, e.g. `QFuture`, or `QNetworkReply`

```
const int theAnswer = co_await QtConcurrent::run([]() {
    std::this_thread::sleep_for(std::chrono::years{7'500'000});
    return 42;
});
```

```
QNetworkAccessManager nam;
const auto *reply = co_await nam.get("https://kde.org/...");
```

QCoro Library - QProcess

Certain types have multiple operations that can be co_awaited – for those QCoro provides wrapper types using `qCoro()`.

```
QProcess process;
process.start("/usr/bin/gpg2", {"-d"});

co_await qCoro(process).waitForStarted();

process.write(encryptedData);
process.closeWriteChannel();

co_await qCoro(process).waitForFinished();
const QByteArray decryptedData = process.readAll();
```

QCoro Library - QTcpServer/QTcpSocket

```
QTcpServer server;
server.listen(…);
while (!stop) {
    auto *socket = co_await qCoro(server).waitForNewConnection(5s);
    if (socket == nullptr) continue;

    co_await qCoro(socket)->waitForReadyRead();
    const auto data = socket->readAll();
    socket->write(“PONG “ + data);
    socket->close();
    delete socket;
}
```

QCoro Library

- `QDBusPendingCall`, `QDBusPendingReply`
- `QFuture`
- `QIODevice`
- `QNetworkReply`
- `QAbstractSocket`, `QLocalSocket`, `QTcpServer`
- `QProcess`
- `QTimer`
- Qt signal

Questions?

QCoro
github.com/danvratil/qcoro
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